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HIGHWAY CONSTRUCTION

PART II

INSTRUCTION PAPER

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HIGHWAY CONSTRUCTION

PART II

STREETS AND HIGHWAYS

CITY STREETS

The first work requiring the skill of the engineer is to lay out town sites properly, especially with reference to the future requirements of a large city where any such possibility exists. Few if any of our large cities were so planned. The same principles, to a limited extent, are applicable to all towns or cities. The topography of the site should be carefully studied, and the street lines adapted to it. These lines should be laid out systematically, with a view to convenience and comfort, and also with reference to economy of construction, future sanitary improvements, grades, and drainage.

Arrangement of City Streets. Generally, the best method of laying out streets is in straight lines, with frequent and regular intersecting streets, especially for the business parts of a city. When there is some centrally located structure, such as a courthouse, city hall, market, or other prominent building, it is very desirable to have several diagonal streets leading thereto. In the residence portions of cities, especially if on hilly ground, curves may with advantage replace straight lines, by affording better grades at less cost of grading, and by improving property through avoiding heavy embankments or cuttings.

Width of Streets. The width of streets should be proportioned to the character of the traffic that will use them. No rule can be laid down by which to determine the best width of streets; but it may safely be said that a street which is likely to become a commercial thoroughfare should have a width of not less than 120 feet between the building lines—the carriage-way 80 feet wide, and the sidewalks each 20 feet wide.

In streets occupied entirely by residences a carriage-way 32 feet wide will be ample, but the width between the building lines may be as great as desired. The sidewalks may be any amount over 10 feet

which fancy dictates. Whatever width is adopted for them, not more of it than 8 feet need be paved, the remainder being occupied with grass and trees.

Street Grades. The grades of city streets depend upon the topography of the site. The necessity of avoiding deep cuttings or high embankments which would seriously affect the value of adjoining property for building purposes, often demands steeper grades than are permissible on country roads. Many cities have paved streets on 20 per cent grades. In establishing grades through unimproved property, they may usually be laid with reference to securing the most desirable percentage within a proper limit of cost. But when improvements have already been made and have been located with reference to the natural surface of the ground, giving a desirable grade is frequently a matter of extreme difficulty without injury to adjoining property. In such cases it becomes a question of how far individual interests shall be sacrificed to the general good. There are, however, certain conditions which it is important to bear in mind:

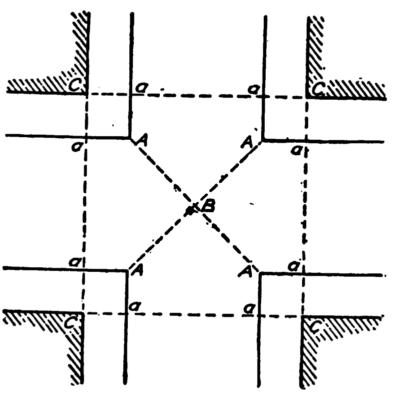

Fig. 47.

(1) That the longitudinal crown level should be uniformly sustained from street to street intersection, whenever practicable.

(2) That the grade should be sufficient to drain the surface.

(3) That the crown levels at all intersections should be extended transversely, to avoid forming a depression at the junction.

Arrangements of Grades at Street Intersections. The best arrangement for intersections of streets when either or both have much inclination, is a matter requiring much consideration, and is one upon which much diversity of opinion exists. No hard or fast rule can be laid down; each will require special adjustment. The best and simplest method is to make the rectangular space *aaaaaaaa*, Fig. 47, level, with a rise of one-half inch in 10 feet from AAAA to B, placing gulleys at AAAA and the catch basins at *ccc*. When this method is not practicable, adopt such a grade (but one not exceeding 2½ per cent)

that the rectangle AAAA shall appear to be nearly level; but to secure this it must actually have a considerable dip in the direction of the slope of the street. If steep grades are continued across intersections, they introduce side slopes in the streets thus crossed, which are troublesome, if not dangerous, to vehicles turning the corners, especially the upper ones. Such intersections are especially objectionable in rainy

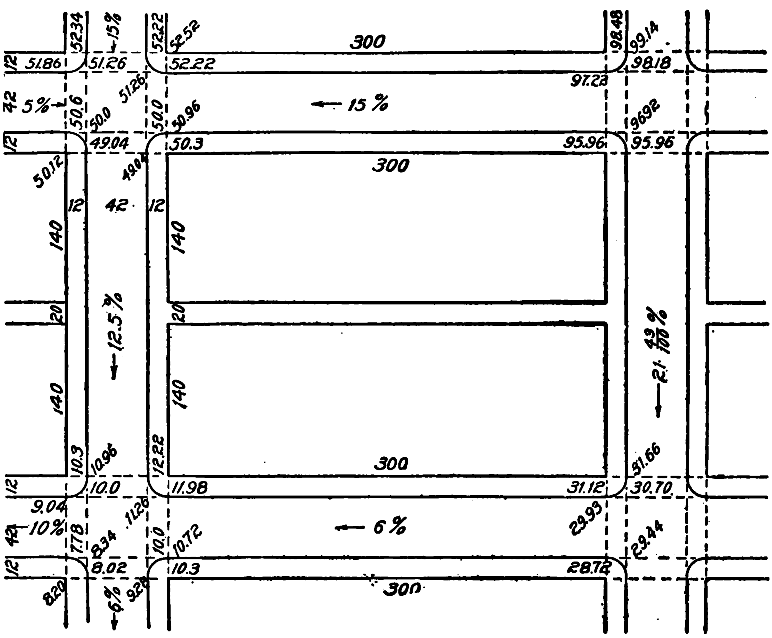

Fig. 48.

weather. The storm water will fall to the lowest point, concentrating a large quantity of water at two receiving basins, which, with a broken grade, could be divided between four or more basins.

Fig. 48 shows the arrangement of intersections in steep grades adapted for the streets of Duluth, Minn. From this it will be seen that at these intersections the grades are flattened to three per cent for the width of the roadway of the intersecting streets, and that the grade of the curbs is flattened to eight per cent for the width of the intersecting sidewalks. Grades of less amount on roadway or sidewalk are continuous. The elevation of block-corners is found by adding together the curb elevations at the faces of the block-corners, and 2½ per cent of

the sum of the widths of the two sidewalks at the corner, and dividing the whole by two. This gives an elevation equal to the average elevation of the curbs at the corners, plus an average rise of two and one-half per cent across the width of the sidewalk.

Accommodation summits have to be introduced between street intersections—first, in hilly localities, to avoid excessive excavation; and second, when the intersecting streets are level or nearly so, for the purpose of obtaining the fall necessary for surface drainage.

The elevation and location of these summits may be calculated as follows: Let A be the elevation of the highest corner; B, the elevation of the lowest corner; D, the distance from corner to corner; and R, the rate of the accommodation grade. The elevation of the summit is equal to

$$\frac{D \cdot R + A + B}{2}.$$

The distance from A or B is found by subtracting the elevation of either A or B from this quotient, and dividing the result by the rate of grade. Or the summits may be located mechanically by specially prepared scales. Prepare two scales divided to correspond to the rate of grade; that is, if the rate of grade be 1 foot per 100 feet, then one division of the scale should equal 100 feet on the map scale. These divisions may be subdivided into tenths. One scale should read from right to left, and one from left to right.

To use the scales, place them on the map so that their figures correspond with the corner elevations; then, as the scales read in op-

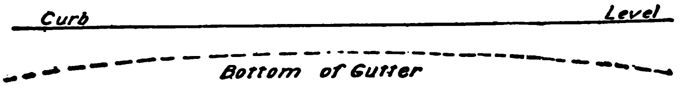

Fig. 49.

posite directions, there is of course some point at which the opposite readings will be the same: this point is the location of the summits; and the figures read off the scale its elevation. If the difference in elevation of the corners is such as not to require an intermediate summit for drainage, it will be apparent as soon as the scales are placed in position.

When an accommodation summit is employed, it should be formed by joining the two straight grade lines by a vertical curve, as

described in Part I. The curve should be used both in the crown of the street and in the curb and footpath.

Where the grade is level between intersections, sufficient fall for surface drainage may be secured without the aid of accommodation summits, by arranging the grades as shown in Fig. 49. The curb is set level between the corners; a summit is formed in the gutter; and receiving basins are placed at each corner.

Transverse Grade. In transverse grade the street should be level; that is, the curbs on opposite sides should be at the same level, and the street crown rise equally from each side to the center. But in hillside streets this condition cannot always be fulfilled, and opposite

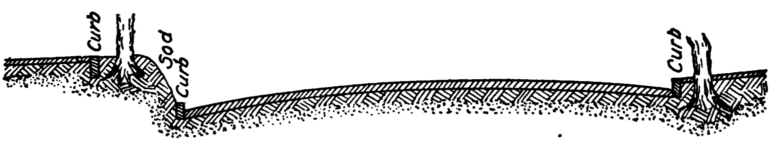

Fig. 50.

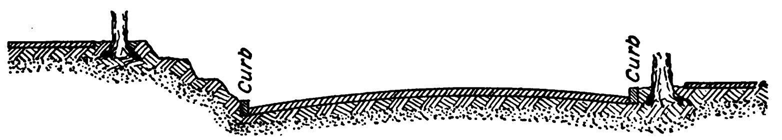

Fig. 51.

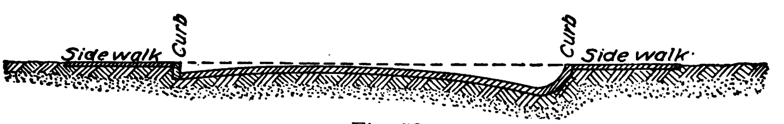

Fig. 52.

sides of the street may differ as much as five feet; in such cases the engineer will have to use his discretion as to whether he shall adopt a straight slope inclining to the lower side, thus draining the whole street by the lower gutter, or adopt the three-curb method and sod the slope of the higher side.

In the improvement of old streets with the sides at different levels, much difficulty will be met, especially where shade trees have to be spared. In such cases, recognized methods have to be abandoned, and the engineer will have to adopt methods of overcoming the difficulties in accordance with the conditions and necessities of each particular case. Figs. 50, 51, and 52 illustrate several typical arrangements in

the case of streets in which the opposite sides are at different levels.

Transverse Contour or Crown. The reason for crowning a pavement—*i. e.*, making the center higher than the sides—is to provide for the rapid drainage of the surface. The most suitable form for the crown is the parabolic curve, which may be started at the curb line, or at the edge of the gutter adjoining the carriage-way about one foot

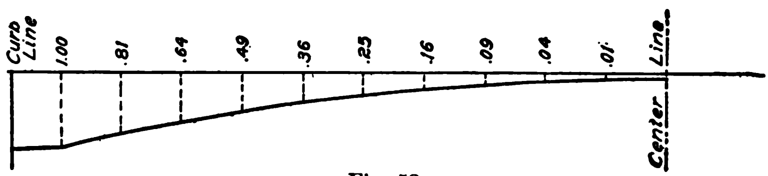

Fig. 53.

from the curb. Fig. 53 shows this form, which is obtained by dividing the ordinate or width from the gutter to the center of the street into ten equal parts, and raising perpendiculars the length of which will be determined by multiplying the rise at the center by the respective number of each perpendicular in the diagram. The amounts thus obtained can be added to the rod readings; and the stakes, set at the proper distance across the street, with their tops at this level, will give the required curve.

The amount of transverse rise, or the height of the center above the gutters, varies with the different paving materials, smooth pavements requiring the least, and rough ones and earth the greatest. The rise is generally stated in a proportion of the width of the carriage-way. The most suitable proportions are:

Stone blocks,	rise at center,	$\frac{1}{80}$	width of carriage-way.
Wood	" " "	$\frac{1}{100}$	" " "
Brick	" " "	$\frac{1}{80}$	" " "
Asphalt	" " "	$\frac{1}{80}$	" " "

Sub-Foundation Drainage of Streets. The sub-foundation drainage of streets cannot be effected by transverse drains, because of their liability to disturbance by the introduction of gas, water, and other pipes.

Longitudinal drains must be depended upon entirely; they may be constructed of the same materials and in the same manner as road drains. The number of these longitudinal drains must depend upon

the character of the soil. If the soil is moderately retentive, a single row of tiles or a hollow invert placed under the sewer in the center of the street will generally be sufficient; or two rows of tiles may be employed, one placed outside each curb line; if, on the other hand, the soil is exceedingly wet and the street very wide, four or more lines may be employed. These drains may be permitted to discharge into the sewers of the transverse streets.

Surface Drainage. The removal of water falling on the street surface is provided for by collecting it in the gutters, from which it is discharged into the sewers or other channels by means of catch-basins placed at all street intersections and dips in the street grades.

Gutters. The gutters must be of sufficient depth to retain all the water which reaches them and prevent its overflowing on the footpath. The depth should never be less than 6 inches, and very rarely need be more than 10 inches.

Catch-basins are of various forms, usually circular or rectangular, built of brick masonry coated with a plaster of Portland cement. Whichever form is adopted, they should fulfil the following conditions:

(1) The inlet and outlet should have sufficient capacity to receive and discharge all water reaching the basin.

(2) The basins should have sufficient capacity below the outlet to retain all sand and road detritus, and prevent it being carried into the sewer.

(3) They should be trapped so as to prevent the escape of sewer gas. (This requirement is frequently omitted, to the detriment of the health of the people.)

(4) They should be constructed so that the pit can easily be cleaned out.

(5) The inlet should be so constructed as not easily to be choked by leaves or debris.

(6) They must offer the least possible obstruction to traffic.

(7) The pipe connecting the basin to the sewer should be easily freed of any obstruction.

The bottom of the basins should be 6 or 8 feet below the street level; and the water level in them should be from 3 to 4 feet lower than the street surface, as a protection against freezing.

The capacity and number of basins will depend upon the area of surface which they drain.

In streets having level or light longitudinal grades, gullies may be formed along the line of the gutter at such intervals as may be found necessary.

Catch-basins are usually placed at the curb line. In several cities, the basin is placed in the center of the street, and connects to inlets placed at the curb line. This reduces the cost of construction and cleaning, and removes from the sidewalk the dirty operations of cleaning the basins.

Catch-basins and gully-pits require to be cleaned out at frequent intervals; otherwise the odor arising from the decomposing matter contained in them will be very offensive. No rule can be laid down for the intervals at which the cleaning should be done, but they must be cleaned often enough to prevent the matter in them from putrefying. There is no uniformity of practice observed by cities in this matter; in some, the cleaning is done but once a year; in others, after every rainstorm; in still others, at intervals of three or four months; while in a few cities the basins are cleaned out once a month.

FOUNDATIONS

The stability, permanence, and maintenance of any pavement depend upon its foundation. If the foundation is weak, the surface will soon settle unequally, forming depressions and ruts. With a good foundation, the condition of the surface will depend upon the material employed for the pavement and upon the manner of laying it.

The essentials necessary to the forming of a good foundation are:

(1) The entire removal of all vegetable, perishable, and yielding matter. It is of no use to lay good material on a bad substratum.

(2) The drainage of the subsoil wherever necessary. A permanent foundation can be secured only by keeping the subsoil dry; for, where water is allowed to pass into and through it, its weak spots will be quickly discovered and settlement will take place.

(3) The thorough compacting of the natural soil by rolling with a roller of proper weight and shape until it forms a uniform and unyielding surface.

(4) The placing on the natural soil so compacted, a sufficient thickness of an impervious and incompressible material to cut off all communication between the soil and the bottom of the pavement.

The character of the natural soil over which the roadway is to be built has an important bearing upon the kind of foundation and the manner of forming it; each class of soil will require its own special

treatment. Whatever its character, it must be brought to a dry and tolerably hard condition by draining and rolling. Sand and gravels which do not hold water, present no difficulty in securing a solid and secure foundation; clays and soils retentive of water are the most difficult. Clay should be excavated to a depth of at least 18 inches below the surface of the finished covering; and the space so excavated should be filled in with sand, furnace slag, ashes, coal dust, oyster shells, broken brick, or other materials which are not excessively absorbent of water. A clay soil or one retaining water may be cheaply and effectually improved by laying cross-drains with open joints at intervals of 50 or 100 feet. These drains should be not less than 18 inches below the surface, and the trenches filled with gravel. They should be 4 inches in internal diameter, and should empty into longitudinal drains.

Sand and planks, gravel, and broken stone have been successively used to form the foundation for pavements; but, although eminently useful materials, their application to this purpose has always been a failure. Being inherently weak and possessing no cohesion, the main reliance for both strength and wear must be placed upon the surface-covering. This covering—usually (except in case of sheet asphalt) composed of small units, with joints between them varying from one-half an inch to one and a-half inches—possesses no elements of cohesion; and under the blows and vibrations of traffic the independent units or blocks will settle and be jarred loose. On account of their porous nature, the subsoil quickly becomes saturated with urine and surface waters, which percolate through the joints; winter frosts upheave them; and the surface of the street becomes blistered and broken up in dozens of places.

Concrete. As a foundation for all classes of pavement (broken stone excepted), hydraulic-cement concrete is superior to any other. When properly constituted and laid, it becomes a solid, coherent mass capable of bearing great weight without crushing. If it fail at all, it must fail altogether. The concrete foundation is the most costly, but this is balanced by its permanence and by the saving in the cost of repairs to the pavement which it supports. It admits of access to subterranean pipes with less injury to the neighboring pavement than any other, for the concrete may be broken through at any point without unsettling the foundation for a considerable distance around it, as is the case with

sand or other incoherent material; and when the concrete is replaced and set, the covering may be reset at its proper level, without the uncertain allowance for settlement which is necessary in other cases.

Thickness of Concrete. The thickness of the concrete bed must be proportioned by the engineer; it should be sufficient to provide against breaking under transverse strain caused by the settlement of the subsoil. On a well-drained soil, six inches will be found sufficient; but in moist and clayey soils, twelve inches will not be excessive. On such soils a layer of sand or gravel, spread and compacted before placing the concrete, will be found very beneficial.

The proportions of the ingredients for concrete used for pavement foundations are usually:

1 part Portland cement
3 parts Sand
7 parts Broken Stone.

Or,

1 part Natural Hydraulic Cement
2 parts Sand
5 parts Broken Stone.

The question is sometimes raised as to whether Natural or Portland cement should be used. Natural cement is more extensively employed on account of its being cheaper in price than Portland. There is no advantage gained in using Portland cement. Concrete should not be laid when the temperature falls below 32° F.

The concrete foundation, after completion, should be allowed to remain several days before the pavement is placed upon it, in order that the mortar may become entirely set. During setting, the concrete should be protected from the drying action of the sun and wind, and should be kept damp to prevent the formation of drying cracks.

STONE BLOCK PAVEMENTS

Stone blocks are commonly employed for pavements where traffic is heavy. The material of which the blocks are made should possess sufficient hardness to resist the abrasive action of traffic, and sufficient toughness to prevent them from being broken by the impact of loaded wheels. The hardest stones will not necessarily give the best results in the pavement, since a very hard stone usually wears smooth and becomes slippery. The edges of the block chip off, and the

upper face becomes rounded, thus making the pavement very rough.

The stone is sometimes tested to determine its strength, resistance to abrasion, etc.; but, as the conditions of use are quite different from those under which it may be tested, such tests are seldom satisfactory. However, examination of a stone as to its structure, the closeness of its grain, its homogeneity, porosity, etc., may assist in forming an idea of its value for use in a pavement. A low degree of permeability usually indicates that the material will not be greatly affected by frost.

Materials.—Granite. Granite is more extensively employed for stone block paving than any other variety of stone; and because of this fact, the term "granite paving" is generally used as being synonymous with stone block paving. The granite employed should be of a tough, homogeneous nature. The hard, quartz granites are usually brittle, and do not wear well under the blows of horses' feet or the impact of vehicles; granite containing a high percentage of feldspar will be injuriously affected by atmospheric changes; and granite in which mica predominates will wear rapidly on account of its laminated structure. Granite possesses the very important property of splitting in three planes at right angles to one another, so that paving blocks may readily be formed with nearly plane faces and square corners. This property is called the *rift* or *cleavage*.

Sandstones of a close-grained, compact nature often give very satisfactory results under heavy traffic. They are less hard than granite, and wear more rapidly, but do not become smooth and slippery. Sandstones are generally known in the market by the name of the quarry or place where produced as "Medina," "Berea," etc.

Trap rock, while answering well the requirements as to durability and resistance to wear, is objectionable on account of its tendency to wear smooth and become slippery; it is also difficult to break into regular shapes.

Limestone has not usually been successful in use for the construction of block pavements, on account of its lack of durability against atmospheric influences. The action of frost commonly splits the blocks; and traffic shivers them, owing to the lamination being vertical.

TABLE 12.

Specific Gravity, Weight, Resistance to Crushing, and Absorption Power of Stones.

MATERIAL	SPECIFIC GRAVITY	WEIGHT Pounds per cu. ft.	RESISTANCE TO CRUSHING Pounds per sq. in.	PERCENTAGE OF WATER ABSORBED
Granite—				
Maximum	2.80	176	35,000	0.155
Minimum	2.60	163	12,000	0.066
Trap—				
Maximum	3.03	178	24,000	0.019
Minimum	2.86	189	19,000	0.000
Sandstone—				
Maximum	2.75	170	18,000	5.480
Minimum	2.23	137	5,000	0.410
Limestone—				
Maximum	2.75	175	20.000	5.000
Minimum	1.90	118	7,000	0.200
Brick Paving—				
Maximum	1.95		20,000	
Minimum	2.55		10,000	

Cobblestone Pavement. Cobblestones bedded in sand possess the merit of cheapness, and afford an excellent foothold for horses; but the roughness of such pavements requires the expenditure of a large amount of tractive energy to move a load over them. Aside from this, cobblestones are entirely wanting in the essential requisites of a good pavement. The stones being of irregular size, it is almost impossible to form a bond or to hold them in place. Under the action of the traffic and frost, the roadway soon becomes a mass of loose stones. Moreover, cobblestone pavements are difficult to keep clean, and very unpleasant to travel over.

Belgian Block Pavement. Cobblestones were displaced by pavements formed of small cubical blocks of stone. This type of pavement was first laid in Brussels, thence imported to Paris, and from there taken to the United States, where it has been widely known as the "Belgian block" pavement. It has been largely used in New York City, Brooklyn, and neighboring towns, the material being trap-rock obtained from the Palisades on the Hudson River.

The stones, being of regular shape, remain in place better than cobblestones; but the cubical form (usually five inches in each dimension) is a mistake. The foothold is bad; the stones wear round; and the number of joints is so great that ruts and hollows are quickly formed. This pavement offers less resistance to traction than cobblestones, but it is almost equally rough and noisy.

Granite Block Pavement. The Belgian block has been gradually

displaced by the introduction of rectangular blocks of granite. Blocks of comparatively large dimensions were at first employed. They were from 6 to 8 inches in width on the surface, from 10 to 20 inches in length, with a depth of 9 inches. They were merely placed in rows on the subsoil, perfunctorily rammed, the joints filled with sand, and the street thrown open to traffic. The unequal settlement of the blocks, the insufficiency of the foothold, and the difficulty of cleansing the street, led to the gradual development of the latest type of stone-block pavement, which consists of narrow, rectangular blocks of granite, properly proportioned, laid on an unyielding and impervious foundation, with the joints between the blocks filled with an impermeable cement.

Experience has proved beyond doubt that this latter type of pavement is the most enduring and economical for roadways subjected to heavy and constant traffic. Its advantages are many, while its defects are few.

Advantages.

(1) Adaptability to all grades.
(2) Suits all classes of traffic.
(3) Exceedingly durable.
(4) Foothold, fair.
(5) Requires but little repair.
(6) Yields but little dust or mud.
(7) Facility for cleansing, fair.

Defects.

(1) Under certain conditions of the atmosphere, the surface of the pavement becomes greasy and slippery.

(2) The incessant din and clatter occasioned by the movement of traffic is an intolerable nuisance; it is claimed by many physicians that the noise injuriously affects the nerves and health of persons who are obliged to live or do business in the vicinity of streets so paved.

(3) Horses constantly employed upon it soon suffer from the continual jarring produced in their legs and hoofs, and quickly wear out.

(4) The discomfort of persons riding over the pavement is very great, because of the continual jolting to which they are subjected.

(5) If stones of an unsuitable quality are used—for example,

those that polish—the surface quickly becomes slippery and exceedingly unsafe for travel.

Size and Shape of Blocks. The proper size of blocks for paving purposes has been a subject of much discussion, and a great variety of forms and dimensions are to be found in all cities.

For stability, a certain proportion must exist between the depth, the length, and the breadth. The depth must be such that when the wheel of a loaded vehicle passes over one edge of the upper surface of a block, the block will not tend to tip up. The resultant direction of the pressure of the load and adjoining blocks should always tend to depress the whole block vertically; where this does not happen, the maintenance of a uniform surface is impossible. To fulfil this requirement, it is not necessary to make the block more than six inches deep.

Width of Blocks. The maximum width of blocks is controlled by the size of horses' hoofs. To afford good foothold to horses drawing heavy loads, it is necessary that the width of each block, measured along the street, shall be the least possible consistent with stability.

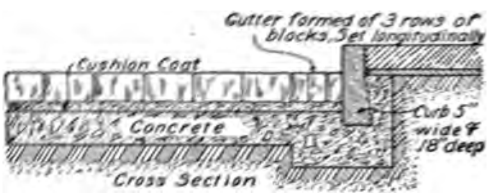

Fig. 54.

If the width be great, a horse drawing a heavy load, attempting to find a joint, slips back, and requires an exceptionally wide joint to pull him up. It is therefore desirable that the width of a block shall not exceed 3 inches; or that four blocks, taken at random and placed side by side, shall not measure more than 14 inches.

Length of Blocks. The length, measured across the street, must be sufficient to break joints properly, for two or more joints in line lead to the formation of grooves. For this purpose the length of the block should be not less than 9 inches nor more than 12 inches.

Form of Blocks. The blocks should be well squared, and must not taper in any direction; sides and ends should be free from irregular projections. Blocks that taper from the surface downwards (wedge-shaped) should not be permitted in the work; but if any are allowed, they should be set with the widest side down.

Manner of Laying Blocks. The blocks should be laid in parallel courses, with their longest side at right angles to the axis of the street, and the longitudinal joints broken by a lap of at least two inches (see Figs. 54 and 55). The reason for this is to prevent the formation of longitudinal ruts, which would happen if the blocks were laid lengthwise. Laying blocks obliquely and "herring-bone" fashion has been

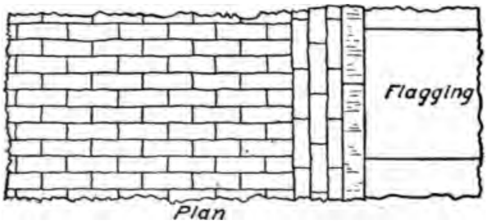

Fig. 55.

tried in several cities, with the idea that the wear and formation of ruts would be reduced by having the vehicle cross the blocks diagonally. The method has failed to give satisfactory results; the wear was irregular and the foothold defective; the difficulty of construction was increased by reason of labor required to form the triangular joints; and the method was wasteful of material.

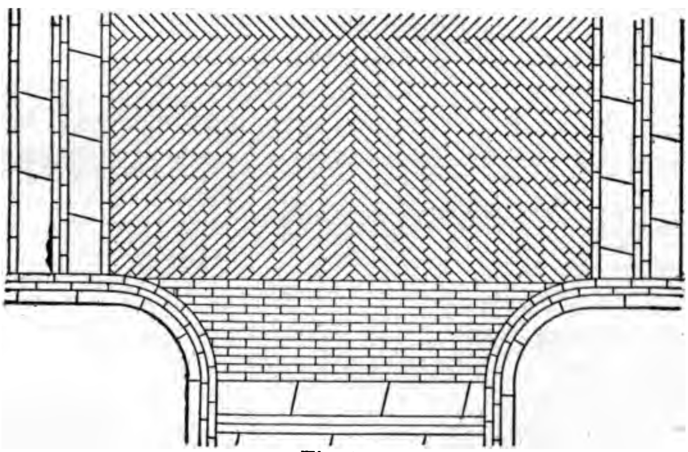
Fig. 56.

The gutters should be formed by three or more courses of block, laid with their length parallel to the curb.

At junctions or intersections of streets, the blocks should be laid diagonally from the center, as shown in Fig. 56. The reasons for

this are: (1) To prevent the traffic crossing the intersection from following the longitudinal joints and thus forming depressions and ruts; (2) Laid in this manner, the blocks afford a more secure foothold for horses turning the corners. The ends of the diagonal blocks where they abut against the straight blocks, must be cut to the required bevel.

The blocks forming each course must be of the same depth, and no deviation greater than one-quarter of an inch should be permitted. The blocks should be assorted as they are delivered, and only those corresponding in depth and width should be used in the same course. The better method would be to gauge the blocks at the quarry. This would lessen the cost considerably; it would also avoid the inconvenience to the public due to the stopping of travel because of the rejection of defective material on the ground. This method would undoubtedly be preferable to the contractor, who would be saved the expense of handling unsatisfactory material; and it would also leave the inspectors free to pay more attention to the manner in which the work of paving is performed.

The accurate gauging of the blocks is a matter of much importance. If good work is to be executed, the blocks, when laid, must be in parallel and even courses; and if the blocks be not accurately gauged to one uniform size, the result will be a badly paved street, with the courses running unevenly. The cost of assorting blocks into lots of uniform width, after delivery on the street, is far in excess of any additional price which would have to be paid for accurate gauging at the quarry.

Foundation. The foundation of the blocks must be solid and unyielding. A bed of hydraulic-cement concrete is the most suitable, the thickness of which must be regulated according to the traffic; the thickness, however, should not be less than 4 inches, and need not be more than 9 inches. A thickness of 6 inches will sustain traffic of 600 tons per foot of width.

Cushion Coat. Between the surface of the concrete and the base of the blocks, there must be placed a cushion-coat formed of an incompressible but mobile material, the particles of which will readily adjust themselves to the irregularities of the bases of the blocks and transfer the pressure of the traffic uniformly to the concrete below. A layer of dry, clean sand 1 to 2 inches thick forms an excellent cushion-coat.

Its particles must be of such fineness as to pass through a No. 8 screen; if coarse and containing pebbles, they will not adapt themselves to the irregularities of the bases of the blocks; hence the blocks will be supported at only a few points, and unequal settlement will take place when the pavement is subjected to the action of traffic. The sand must also be perfectly free from moisture, and artificial heat must be used to dry it if necessary. This requirement is an absolute necessity. There should be no moisture below the blocks when laid; nor should water be allowed to penetrate below the blocks; if such happens, the effect of frost will be to upheave the pavement and crack the concrete.

Where the best is desired without regard to cost, a layer half an inch thick of asphaltic cement may be substituted for the sand, with superior and very satisfactory results.

Laying Blocks. The blocks should be laid stone to stone, so that the joint may be of the least possible width; wide joints cause increased wear and noise, and do not increase the foothold. The courses should be commenced on each side and worked toward the middle; and the last stone should fit tightly.

Ramming. After the blocks have been set, they should be well rammed down; and the stones which sink below the general level should be taken up and replaced with a deeper stone or brought to level by increasing the sand bedding.

The practice of workmen is invariably to use the rammer so as to secure a fair surface. This is not the result intended to be secured, but to bring each block to an unyielding bearing. The result of such a surfacing process is to produce an unsightly and uneven roadway when the pressure of traffic is brought upon it. The rammer used should weigh not less than 50 pounds and have a diameter of not less than 3 inches.

Joint Filling. All stone block pavements depend for their waterproof qualities upon the character of the joint filling. Joints filled with sand and gravel are of course pervious. A grout of lime or cement mortar does not make a permanently waterproof joint; it becomes disintegrated under the vibration of traffic. An impervious joint can be made only by employing a filling made from bituminous or asphaltic material; this renders the pavement more impervious to moisture, makes it less noisy, and adds considerably to its strength.

Bituminous Cement for Joint Filling. The bituminous materials

employed are: (1) The tar produced in the manufacture of gas, which, when redistilled, is called *distillate,* and is numbered 1, 2, 3, 4, etc., according to its density; this material under the name of paving-pitch is extensively used, both alone and in combination with other bituminous substances; (2) Combinations of gas tar or coal tar with refined asphaltum; (3) Mixtures of refined asphaltum, creosote, and coal tar.

The formula for the bituminous joint filling used in New York City, is:

Refined Trinidad asphaltum	20 parts.
No. 4 coal-tar distillate	100 parts.
Residuum of petroleum	3 parts.

In Washington, D. C., coal tar distillate No. 6 is used alone.

In Europe a bituminous cement much used is composed of coal-tar, asphaltum, gas tar, and creosote oil, in the proportion of 100 pounds of asphaltum to 4 gallons of tar and 1 gallon of creosote. These proportions are varied somewhat, according to the quality of the asphaltum employed. The mixture is melted, and is boiled from one to two hours in a suitable boiler, being then poured into the joints in a boiling state. This mixture is impervious to moisture, and possesses a degree of elasticity sufficient to prevent it from cracking.

The mode of applying the bituminous cement is as follows: After the blocks are rammed, the joints are filled to a depth of about two inches with clean gravel heated to a temperature of about 250° F.; then the hot cement is poured in until it forms a layer of about one inch on top of the gravel; then more gravel is filled in to a depth of about two inches; then cement is poured in until it appears on top of the gravel, more gravel being next added until it reaches to within half an inch of the top of the blocks; this remaining half-inch is filled with cement, and then fine gravel or sand is sprinkled over the joints.

In some cases the joints are first filled with heated gravel; the cement is poured in until the sand beneath and the gravel between the blocks will absorb no more, and the joints are filled flush with the top of the pavement. This method is open to objection; for, if the gravel is not sufficiently hot, the cement will be chilled and will not flow to the bottom of the joint, but, instead, will form a thin layer near the surface, which under the action of frost and the vibration of traffic, will be quickly cracked and broken up; the gravel will settle, and the

blocks will be jarred loose, the surface of the pavement becoming a series of ridges and hollows.

The quantity of cement required per square yard of pavement will vary according to the shape of the blocks, the width of the joints, and the depth of the sand bed. With well-shaped blocks, close joints, and a half-inch sand bed, the quantity will vary from 3½ to 5 gallons; with ill-shaped blocks, wide joints, and a heavy sand bed, 10 to 12 gallons

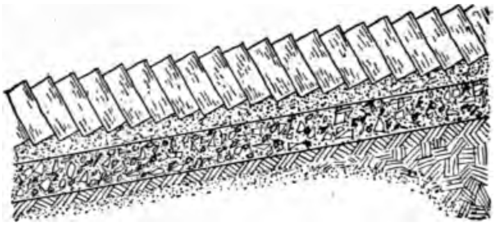

Fig. 57.

would not be an excessive amount to use to secure the result obtained by employing well-shaped blocks and close joints.

Stone Pavement on Steep Grades. Stone blocks may be employed on all practicable grades; but on grades exceeding 10 per cent, cobblestones afford a better foothold than blocks. The cobblestones should be of uniform length, the length being at least twice the breadth —say stones 6 inches long and 2½ to 3 inches in diameter. These should be set on a concrete foundation, laid stone to stone, and the

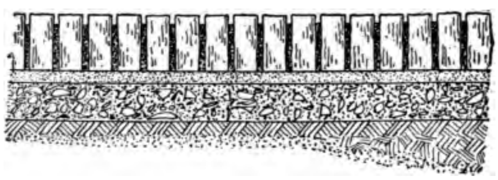

Fig. 58.

interstices filled with cement grout or bituminous cement; or a bituminous concrete foundation may be employed and the interstices between the stones filled with asphaltic paving cement. Should stone blocks be preferred, they must be laid, when the grade exceeds 5 per cent, with a serrated surface, by either of the methods shown in Figs. 57 and 58. The method shown in Fig. 57 consists in slightly tilting the blocks on their bed so as to form a series of ledges or steps, against which the horses' feet being planted, a secure foothold is obtained. The method shown in Fig. 58 consists in placing between the rows of

stones a course of slate, or strips of creosoted wood, rather less than one inch in thickness and about an inch less in depth than the blocks; or the blocks may be spaced about one inch apart, and the joints filled with a grout composed of gravel and cement. The pebbles of the gravel should vary in size between one-quarter and three-quarters of an inch.

BRICK PAVEMENTS

Characteristics of Brick Suitable for Paving. These are:

(1) Not to be acted upon by acids.

(2) Not to absorb more than 1-600 of its weight of water in 48 hours.

(3) Not susceptible to polish.

(4) Rough to the touch, resembling fine sandpaper.

(5) To give a clear, ringing sound when struck together.

(6) When broken, to show a compact, uniform, close-grained, structure, free from air-holes and pebbles.

(7) Not to scale, spall, or chip when quickly struck on the edges.

(8) Hard but not brittle.

Tests of Paving Brick. To ascertain the quality of paving brick, they are generally subjected to four tests, namely: (1) Abrasion by impact (commonly called the "Rattler" test); (2) absorption; (3) transverse or cross-breaking; (4) crushing. With a view to securing uniformity in the methods of making the above tests, the National Brick Manufacturers' Association has adopted and recommends the following:

Rattler Test

1. *Dimensions of the Machine.* The standard machine shall be 28 inches in diameter and 20 inches in length, measured inside the chamber.

Other machines may be used, varying in diameter between 26 and 30 inches, and in length between 18 and 24 inches; but if this is done, a record of it must be attached to the official report. Long rattlers may be cut up into sections of suitable length by the insertion of an iron diaphragm at the proper point.

2 *Construction of the Machine.* The barrel shall be supported on trunnions at either end; in no case shall a shaft pass through the rattling chamber. The cross-section of the barrel shall be a regular polygon having 14 sides. The heads shall be composed of gray cast-

iron, not chilled or case-hardened. The staves shall preferably be composed of steel plates, since cast-iron peans and ultimately breaks under the wearing action on the inside. There shall be a space of one-fourth of an inch between the staves, for the escape of dust and small pieces of waste. Other machines may be used, having from twelve to sixteen staves; but if this is done, a record of it must be attached to the official report of the test.

3. *Composition of the Charge.* All tests must be executed on charges containing but one make of brick or block at a time. The charge shall consist of 9 paving blocks or 12 paving bricks, together with 300 pounds of shot made of ordinary machinery cast-iron. This shot shall be of two sizes, as described below; and the shot charge shall be composed one-fourth (75 pounds) of the larger size, and three-fourths (225 pounds) of the smaller size.

4. *Size of the Shot.* The larger size shall weigh about 7½ pounds and be about 2½ inches square and 4½ inches long, with slightly rounded edges. The smaller size shall be cubes of 1½ inches on a side, with rounded edges. The individual shot shall be replaced by new ones when they have lost one-tenth of their original weight.

5. *Revolutions of the Charge.* The number of revolutions of a standard test shall be 1,800; and the speed of rotation shall not fall below 28 nor exceed 30 revolutions per minute. The belt-power shall be sufficient to rotate the rattler at the same speed, whether charged or empty.

6. *Condition of the Charge.* The bricks composing a charge shall be thoroughly dried before making the test.

7. *Calculation of the Results.* The loss shall be calculated in per cents of the weight of the dry brick composing the charge; and no result shall be considered as official unless it is the average of two distinct and complete tests made on separate charges of brick.

Absorption Test

1. The number of bricks for a standard test shall be five.

2. The test must be conducted on rattled brick. If none such are available, the whole brick must be broken in halves before treatment.

3. Dry the bricks for 48 hours at a temperature ranging from 230° to 250° F. before weighing for the official dry weight.

4. Soak for 48 hours completely immersed in pure water.

5. After soaking, and before weighing, the bricks must be wiped dry from surplus water.

6. The difference in the weight must be determined on scales sensitive to one gram.

7. The increase in weight due to water absorbed shall be calculated in per cents of the initial dry weight.

Cross-Breaking Test

1. Support the brick on edge, or as laid in the pavement, on hardened steel knife-edges, rounded longitudinally to a radius of twelve inches and transversely to a radius of one-eighth inch, and bolted in position so as to secure a span of six inches.

2. Apply the load to the middle of the top face through a hardened steel knife-edge, straight longitudinally and rounded transversely to a radius of one-sixteenth inch.

3. Apply the load at a uniform rate of increase till fracture ensues.

4. Compute the modulus of rupture by the formula

$$f = \frac{3wl}{2bd^2},$$

in which f = modulus of rupture, in pounds per square inch;

w = total breaking load, in pounds;

l = length of span, in inches = 6;

b = breadth of brick, in inches;

d = depth of brick, in inches.

5. Samples for test must be free from all visible irregularities of surface or deformities of shape, and their upper and lower faces must be practically parallel.

6. Not less than ten brick shall be broken, and the average of all shall be taken for a standard test.

Crushing Test

1. The crushing test should be made on half-bricks, loaded edgewise, or as they are laid in the street. If the machine used is unable to crush a full half-brick, the area may be reduced by chipping off, keeping the form of the piece to be tested as nearly prismatic as possible. A machine of at least 100,000 pounds' capacity should be used; and the specimen should not be reduced below four square inches of area in cross-section at right angles to direction of load.

2. The upper and lower surfaces should preferably be ground to

true and parallel planes. If this is not done, they should be bedded, while in the testing machine, in plaster of Paris, which should be allowed to harden ten minutes under weight of the crushing planes only, before the load is applied.

3. The load should be applied at a uniform rate of increase to the point of rupture.

4. Not less than an average obtained from five tests on five different bricks shall constitute a standard test.

Properties of Paving Bricks. Paving bricks range in weight from $5\frac{1}{2}$ to $7\frac{1}{2}$ pounds; in specific gravity, from 1.91 to 2.70; in resistance to crushing, from 7,000 to 18,000 pounds per square inch; in resistance to cross-breaking, R = 1,400 to 2,000 pounds; in absorption, from 0.15 to 3 per cent in 24 hours. The dimensions vary according to locality and the requirements of the specifications. The "standard" bricks are $2\frac{1}{2} \times 4 \times 8$ inches, requiring 58 bricks to the square yard, and weighing 7 pounds each; "repressed", $2\frac{1}{2} \times 4 \times 8\frac{1}{2}$ inches, requiring 61 to the square yard, and weighing $6\frac{1}{2}$ pounds each; "Metropolitan", $3 \times 4 \times 9$ inches, requiring 45 to the square yard, and weighing $9\frac{1}{2}$ pounds each.

Advantages of Brick Pavements. These may be stated as follows:

(1) Ease of traction.
(2) Good foothold for horses.
(3) Not disagreeably noisy.
(4) Yields but little dust and mud.
(5) Adapted to all grades.
(6) Easily repaired.
(7) Easily cleaned.
(8) But slightly absorbent.
(9) Pleasing to the eye.
(10) Expeditiously laid.
(11) Durable under moderate traffic.

Defects of Brick Pavements. The principal defects of brick pavements arise from lack of uniformity in the quality of the bricks, and from the liability of incorporating in the pavement bricks of too soft or porous a structure, which crumbles under the action of traffic or frost.

Foundation. A brick pavement should have a firm foundation. As the surface is made up of small, independent blocks, each one must

be adequately supported, or the load coming upon it may force it downwards and cause unevenness, a condition which conduces to the rapid destruction of the pavement. Several forms of foundation have been used—such as gravel, plank, sand, broken stone, and concrete. The last mentioned is doubtless the best.

Sand Cushion. The sand cushion is a layer of sand placed on top of the concrete to form a bed for the brick. Practice regarding the depth of this layer of sand varies considerably. In some cases it is only half an inch deep, varying from this up to three inches. The sand cushion is very desirable, as it not only forms a perfectly true and even surface upon which to place brick, but also makes the pavement less hard and rigid than would be the case were the brick laid directly on the concrete.

The sand is spread evenly, sprinkled with water, smoothed, and brought to the proper contour by screeds or wooden templets, properly trussed, mounted on wheels or shoes which bear upon the upper surface of the curb. Moving the templet forward levels and forms the sand to a uniform surface and proper shape.

The sand used for the cushion-coat should be clean and free from loam, moderately coarse, and free from pebbles exceeding one-quarter inch in size.

Manner of Laying. The bricks should be laid on edge, as closely and compactly as possible, in straight courses across the street, with the length of the bricks at right angles to the axis of the street. Joints should be broken by at least 3 inches. None but whole bricks should be used, except in starting a course or making a closure. To provide for the expansion of the pavement, both longitudinal and transverse expansion-joints are used, the former being made by placing a board templet seven-eighths of an inch thick against the curb and abutting the brick thereto. The transverse joints are formed at intervals varying between 25 and 50 feet, by placing a templet or building-lath three-eighths of an inch thick between two or three rows of brick. After the bricks are rammed and ready for grouting, these templets are removed, and the spaces so left are filled with coal-tar pitch or asphaltic paving cement. The amount of pitch or cement required will vary between one and one and a-half pounds per square yard of pavement, depending upon the width of the joints. After 25 or 30 feet of the pavement is laid, every part of it should be rammed with a rammer

weighing not less than 50 pounds; and the bricks which sink below the general level should be removed, sufficient sand being added to raise the brick to the required level. After all objectionable brick have been removed, the surface should be swept clean, then rolled with a steam roller weighing from 3 to 6 tons. The object of rolling is to bring the bricks to an unyielding bearing with a plane surface; if this is not done, the pavement will be rough and noisy and will lack dura-

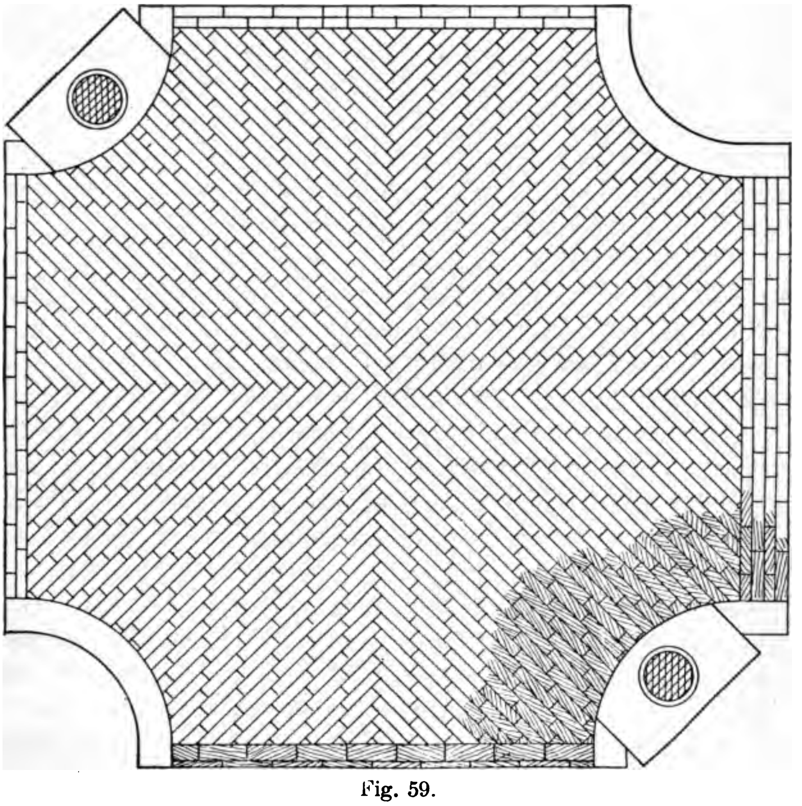

Fig. 59.

bility. The rolling should be first executed longitudinally, beginning at the crown and working toward the gutter, taking care that each return trip of the roller covers exactly the same area as the preceding trip, so that the second passage may neutralize any careening of the brick due to the first passage.

The manner of laying brick at street intersections is shown in Fig. 59.

Joint Filling. The character of the material used in filling the joints between the brick has considerable influence on the success and durability of the pavement. Various materials have been used—such as sand, coal-tar pitch, asphalt, mixtures of coal-tar and asphalt, and Portland cement, besides various patented fillers, as "Murphy's grout", which is made from ground slag and cement. Each material has its advocates, and there is much difference of opinion as to which gives the best results.

The best results seem to be obtained by using a high grade of Portland cement containing the smallest amount of lime in its composition, the presence of the lime increasing the tendency of the filler to swell through absorption of moisture, causing the pavement to rise or to be lifted away from its foundation, and thus producing the roaring or rumbling noise so frequently complained of.

The Portland cement grout, when uniformly mixed and carefully placed, resists the impact of traffic and wears well with brick. When a failure occurs, repairs can be made quickly; and, if made early, the pavement will be restored to a good condition. If, however, repairs are neglected, the brick soon loosens and the pavement fails.

The office of a filler is to prevent water from reaching the foundation, and to protect the edges of the brick from spalling under traffic. In order to meet both of these requirements, every joint must be filled to the top, and must remain so, wearing down with the brick. Sand does not meet these requirements. Although at first making a good filler, being inexpensive and reducing the liability of the pavement to be noisy, it soon washes out, leaving the edges of the brick unprotected and consequently liable to be chipped. Coal-tar and the mixtures of coal-tar and asphalt have an advantage in rendering a pavement less noisy and in cementing together any breaks that may occur through upheavals from frost or other causes; but, unless made very hard, they have the disadvantage of becoming soft in hot weather and flowing to the gutters and low places in the pavement, there forming a black and unsightly scale and leaving the high parts unprotected. The joints, thus deprived of their filling, become receptacles for water, mud, and ice in turn; and the edges of the brick are quickly broken down. Some of these mixtures become so brittle in winter that they crack and fly out of the joints under the action of traffic.

The Portland cement filler is prepared by mixing two parts of

cement and one part of fine sand with sufficient water to make a thin grout. The most convenient arrangement for preparing and distributing the grout is a water-tight wooden box carried on four wooden wheels about 12 inches in diameter. The box may be about 4 feet wide, 7 feet long, and 12 inches deep, furnished with a gate about 8 inches wide, in the rear end. The box should be mounted on the wheels with an inclination, so that the rear end is about 4 inches lower than the front end.

The operation of placing the filler is as follows: The cement and sand are placed in the box, and sufficient water is added to make a thin grout. The box is located about 12 feet from the gutter, the end gate opened, and about 2 cubic feet of the grout allowed to flow out and run over the top of the brick (care being taken to stir the grout while it is being discharged). If the brick are very dry, the entire surface of the pavement should be thoroughly wet with a hose before applying the grout; if not, absorption of the water from the grout by the bricks will prevent adhesion between the bricks and the cement grout. The grout is swept into the joints by ordinary bass brooms. After about 100 feet in length of the pavement has been covered the box is returned to the starting-point, and the operation is repeated with a grout somewhat thicker than the first. If this second application is not sufficient to fill the joints, the operation is repeated as often as may be necessary to fill them. If the grout has been made too thin, or the grade of the street is so great that the grout will not remain long enough in place to set, dry cement may be sprinkled over the joints and swept in. After the joints are completely filled and inspected, allowing three or four hours to intervene, the completed pavement should be covered with sand to a depth of about half an inch, and the roadway barricaded, and no traffic allowed on it for at least ten days.

The object of covering the pavement with sand is to prevent the grout from drying or settling too rapidly; hence, in dry and windy weather, it should be sprinkled from time to time. If coarse sand is employed in the grout, it will separate from the cement during the operation of filling the joints, with the result that many joints will be filled with sand and very little cement, while others will be filled with cement and little or no sand; thus there will be many spots in the pavement in which no bond is formed between the bricks, and under the action of traffic these portions will quickly become defective.

The coal-tar filler is best applied by pouring the material from buckets, and brooming it into the joints with wire brooms. In order to fill the joints effectually, it must be used only when very hot. To secure this condition, a heating tank on wheels is necessary. It should have a capacity of at least five barrels, and be kept at a uniform temperature all day. One man is necessary to feed the fire and draw the material into the buckets; another, to carry the buckets from the heating-tank to a third, who pours the material over the street. The latter starts to pour in the center of the street, working backward toward the curb, and pouring a strip about two feet in width. A fourth man, with a wire broom, follows immediately after him, sweeping the surplus material toward the pourer and in the direction of the curb. This method leaves the entire surface of the pavement covered with a thin coating of pitch, which should immediately be covered with a light coating of sand; the sand becomes imbedded in the pitch. Under the action of traffic, this thin coating is quickly worn away, leaving the surface of the bricks clean and smooth.

Tools Employed in Construction of Block Pavements. The principal tools required in constructing block pavements comprise *hammers* and *rammers* of varying sizes and shapes, depending on the material and size of the blocks to be laid; also *crowbars*, *sand screens*, and rattan and wire *brooms*. Cobblestones, square blocks, and brick require different types of both hammers and rammers for adjusting them to place and forcing them to their seat. A cobblestone rammer, for example, is usually made of wood (generally locust) in the shape of a long truncated cone, banded with iron at top and bottom, weighing about 40 pounds, and having two handles, one at the top and another on one side. A Belgian block rammer is slightly heavier, consisting of an upper part of wood set in a steel base; while a rammer for granite blocks is still heavier, comprising an iron base with cast-steel face, into which is set a locust plug with hickory handles. For laying brick, a wooden rammer shod with cast iron or steel and weighing about 27 pounds is used. A light rammer of about 20 pounds' weight, consisting of a metallic base attached to a long, slim wooden handle, is used for miscellaneous work, such as tamping in trenches, next to curbs, etc.

Concrete-Mixing Machine. Where large quantities of concrete are required, as in the foundations of improved pavements, concrete can be prepared more expeditiously and economically by the use of

mechanical mixers, and the ingredients will be more thoroughly mixed, than by hand. Thorough incorporation of the ingredients is an essential element in the quality of a concrete. When mixed by hand, however, the incorporation is rarely complete, because it depends upon the proper manipulation of the hoe and shovel. The manipulation, although extremely simple, is rarely performed by the ordinary laborer unless he is constantly watched by the overseer.

Several varieties of concrete-mixing machines are in the market. A convenient portable type is illustrated in Fig. 60. The capacity of

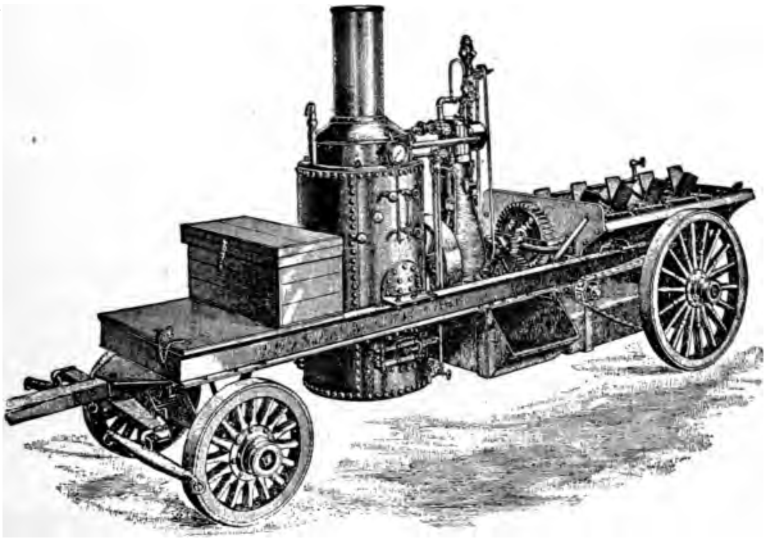

Fig. 60. Concrete Mixing Machine.

the mixers ranges from five to twenty cubic yards per hour, depending upon size, regularity with which the materials are supplied, speed, etc.

Gravel Heaters. Fig. 61 illustrates a device commonly employed for heating the gravel used for joint filling in stone-block pavements. These heaters are made in various sizes, a common size being 9 feet long, 5 feet wide, and 3 feet 9 inches high.

Melting Furnaces, for heating the pitch or tar for joint filling, are illustrated by Fig. 62. Various sizes are on the market.

WOOD PAVEMENTS

Wood pavements are formed of either rectangular or cylindrical blocks of wood. The rectangular blocks are generally 3 inches wide,

9 inches long, and 6 inches deep; the round blocks are commonly 6 inches in diameter and 6 inches long.

The kinds of wood most commonly used are cedar, cypress, juniper, yellow pine, and mesquite; and recently *jarrah* from Australia, and *pyingado* from India, have been used.

The wood is used in its natural condition, or impregnated with creosote or other chemical preservative.

The blocks of wood are laid either on the natural soil, on a bed of sand and gravel, on a layer of broken stone, on a layer of concrete,

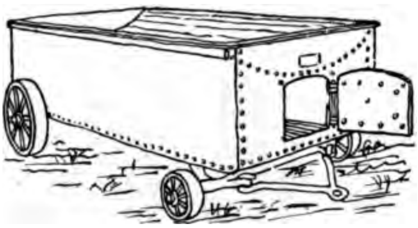

Fig. 61. Gravel Heater.

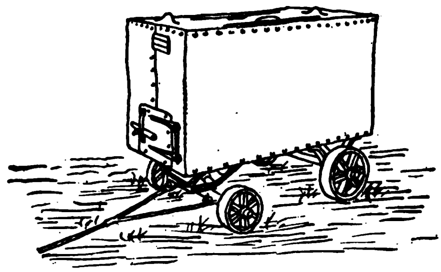

Fig. 62. Melting Furnace.

or, sometimes, on a double layer of plank. The joints are filled either with sand, paving-pitch, or Portland-cement grout.

Advantages. The advantages of wood pavement may be stated as follows:

(1) It affords good foothold for horses.

(2) It offers less resistance to traction than stone, and slightly more than asphalt.

(3) It suits all classes of traffic.

(4) It may be used on grades up to five per cent.

(5) It is moderately durable.

(6) It yields no mud when laid upon an impervious foundation.

(7) It yields but little dust.

(8) It is moderate in first cost.

(9) It is not disagreeably noisy.

Defects. The principal objections to wood pavement are:

(1) It is difficult to cleanse.

(2) Under certain conditions of the atmosphere it becomes greasy and very unsafe for horses.

(3) It is not easy to open for the purpose of gaining access to underground pipes, it being necessary to remove rather a large surface for this purpose, which has to be left a little time after being repaired before traffic is again allowed upon it.

(4) It is absorbent of moisture.

(5) It is claimed by many that wood pavements are unhealthy.

Quality of Wood. The question as to which of the various kinds of wood available is the most durable and economical, has not been satisfactorily determined. Many varieties have been tried. In England, preference is given to Baltic fir, yellow pine, and Swedish yellow deal. In the United States the variety most used (on account of its abundance and cheapness) is cedar; but yellow pine, tamarack, and mesquite have also been used to a limited extent, and cypress and juniper are being largely used in some of the Southern States.

Hardwoods, such as oak, etc., do not make the best pavements, as such woods become slippery. The softer, close-grained woods, such as cedar and pine, wear better and give good foothold.

The wood employed should be sound and seasoned, free from sap, shakes, and knots. Defective blocks laid in the pavement will quickly cause holes in the surface, and the adjoining blocks will suffer under wear, the whole surface becoming bumpy.

Chemical Treatment of Wood. The great enemy of all wood pavements is decay, induced by the action of the air and water. Wood is porous, absorbs moisture, and thus hastens its own destruction. Many processes have been invented to overcome this defect. The most popular processes at present are *creosoting* and modifications of the same, known as the "creo-resinate" and "kreodine" processes. These consist of creosote mixed with various chemicals which are supposed to add to the preserving qualities of the creosote.

Creosoting. This process consists in impregnating the wood with the oil of tar, called *creosote*, from which the ammonia has been expelled, the effect being to coagulate the albumen and thereby prevent

its decomposition, also to fill the pores of the wood with a bituminous substance which excludes both air and moisture, and which is noxious to the lower forms of animal and vegetable life. In adopting this process, all moisture should be dried out of the pores of the timber. The softer woods, while warm from the drying-house, may be immersed at once in an open tank containing hot creosote oil, when they will absorb about 8 or 9 pounds per cubic foot. For hardwoods, and woods which are required to absorb more than 8 or 9 pounds of creosote per cubic foot, the timber should be placed in an iron cylinder with closed ends, and the creosote, which should be heated to a temperature of about 120° F., forced in with a pressure of 170 pounds to the square inch. The heat must be kept up until the process is complete, to prevent the creosote from crystallizing in the pores of the wood. By this means the softer woods will easily absorb from 10 to 12 pounds of oil per cubic foot.

The most effective method, however, is to exhaust the air from the cylinder after the timber is inserted; then to allow the oil to flow in; and when the cylinder is full, to use a force pump with a pressure of 150 to 200 pounds per square inch, until the wood has absorbed the requisite quantity of oil, as indicated by a gauge, which should be fitted to the reservoir tank.

The oil is usually heated by coils of pipe placed in the reservoir, through which a current of steam is passed.

The quantity of creosote oil recommended to be forced into the wood is from 8 to 12 pounds per cubic foot. Into oak and other hard woods it is difficult to force, even with the greatest pressure, more than 2 or 3 pounds of oil.

The advantages of this process are: The chemical constituents of the oil preserve the fibers of the wood by coagulating the albumen of the sap; the fatty matters act mechanically by filling the pores and thus exclude water; while the carbolic acid contained in the oil is a powerful disinfectant.

The life of the wood is extended by any of the above processes, by preserving it from decay; but such processes have little or no effect on the wear of the blocks under traffic.

The process of dipping the blocks in coal tar or creosote oil is injurious. Besides affording a cover for the use of defective or sappy wood, it hastens decay, especially of green wood; it closes up the ex-

terior of the cells of the wood so that moisture cannot escape, thus causing fermentation to take place in the interior of the block, which quickly destroys the strength of the fibers and reduces them to punk.

Expansion of Blocks. Wood blocks expand on exposure to moisture; and, when they are laid end to end across the street, the curbstones are liable to be displaced, or the courses of the blocks will be bent into reserve curves. To avoid this, the joints of the courses near the curb may be left open until expansion has ceased, the space being temporarily filled with sand. The rate of expansion is about 1 inch in 8 feet, but varies for different woods. The time required for the wood to become fully expanded varies from 12 to 18 months. By employing blocks impregnated with the oil of creosote, this trouble will be avoided. Blocks so treated do not contract or expand to any appreciable extent.

The comparative expansion of creosoted and plain wood blocks after immersion in water for forty-eight hours, in percentage on original dimensions, was:

Expansion of Wood Paving Blocks

Dimension	Creosoted	Plain
On length of block	.099	.6
On width " "	.57	.83
On depth " "	.15	.31

Manner of Laying. The blocks are set with the fiber vertical, and the long dimension crosswise of the street, the longitudinal joints being broken by a lap of at least one-third the length of the block; the

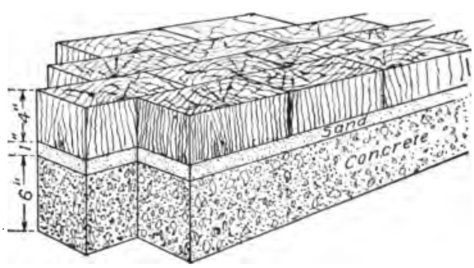

Fig. 63.

blocks should be laid so as to have the least possible width of joint. Wide joints hasten the destruction of the wood by permitting the fibers to wear under traffic, which also causes the surface of the pavement

to wear in small ridges. The most recent practice for laying blocks on 3 per cent grades, has been to remove from the top of one side of each block a strip ¼ inch thick and 1½ inches deep, extending the length of the block. When the blocks are laid and driven closely together, there is a quarter-inch opening or joint extending clear across the street in each course. These joints are filled with Portland cement grout. Fig. 63 shows a section of pavement having this form of joint.

Filling for Joints. The best materials for filling the joints are bitumen for the lower two or three inches, and hydraulic cement grout for the remainder of the depth. The cement grout protects the pitch from the action of the sun, and does not wear down very much below the surface of the wood.

ASPHALT PAVEMENTS.

Asphaltic Paving Materials. All asphaltic or bituminous pavements are composed of two essential parts—namely, the cementing material (*matrix*) and the resisting material (*aggregate*). Each has a distinct function to perform; the first furnishes and preserves the coherency of the mass; the second resists the wear of traffic.

Two classes of asphaltic paving compounds are in use,—namely, *natural* and *artificial*. The "natural" variety is composed of either limestone or sandstone naturally cemented with bitumen. To this class belong the bituminous limestones of Europe, Texas, Utah, etc., and the bituminous sandstones of California, Kentucky, Texas, Indian Territory, etc. The "artificial" consists of mixtures of asphaltic cement with sand and stone dust. To this class belong the pavements made from Trinidad, Bermudez, Cuban, and similar asphaltums. For the artificial variety, most hard bitumens are, when properly prepared, equally suitable. For the aggregate, the most suitable materials are stone-dust from the harder rocks, such as granite, trap, etc., and sharp angular sand. These materials should be entirely free from loam and vegetable impurities. The strength and enduring qualities of the mixture will depend upon the quality, strength, and proportion of each ingredient, as well as upon the cohesion of the matrix and its adhesion to the aggregate.

Bituminous limestone consists of carbonate of lime naturally cemented with bitumen in proportions varying from 80 to 93 per cent of carbonate of lime and from 7 to 20 per cent of bitumen. Its color, when freshly broken, is a dark (almost black) chocolate brown, the

darker color being due to a large percentage of bitumen. At a temperature of from 55° to 70° F., the material is hard and sonorous, and breaks easily with an irregular fracture; at temperatures between 70° and 140° F. it softens, passing with the rise in temperature through various degrees of plasticity, until, at between 140° and 160° F., it begins to crumble; at 212° it commences to melt; and at 280° F. it is completely disintegrated. Its specific gravity is about 2.235.

Bituminous limestone is the material employed for paving purposes throughout Europe. It is obtained principally from deposits at Val-de-Travers, canton of Neufchatel, Switzerland; at Seysell, in the Department of Ain, France; at Ragusa, Sicily; at Limmer, near Hanover; and at Vorwohle, Germany.

Bituminous limestone is found in several parts of the United States. Two of these deposits are at present being worked—one in Texas, the material from which is called "lithocarbon"; and one on the Wasatch Indian Reservation. These deposits contain from 10 to 30 per cent of bitumen.

The bituminous limestones which contain about 10 per cent of bitumen are used for paving in their natural condition, being simply reduced to powder, heated until thoroughly softened, then spread while hot upon the foundation, and tamped and rammed until compacted.

Bituminous sandstones are composed of sandstone rock impregnated with bitumen in amounts varying from a trace to 70 per cent. They are found in both Europe and America. In Europe, they are chiefly used for the production of pure bitumen, which is extracted by boiling or macerating them with water. In the United States, extensive deposits are found in the Western States; and since 1880 they have been gradually coming into use as a paving material, so that now upwards of 150 miles of streets in Western cities are paved with them. They are prepared for use as paving material by crushing to powder, which is heated to about 250° F. or until it becomes plastic, then spread upon the street and compressed by rolling; sometimes sand or gravel is added, and it is stated that a mixture of about 80 per cent of gravel makes a durable pavement.

Trinidad Asphaltum. The deposits of asphaltum in the island of Trinidad, W. I., have been the main source of supply for the asphaltum used in street paving in the United States. Three kinds are found there, which have been named, according to the source, *lake-pitch*,

land or *overflow pitch,* and *iron pitch.* The first and most valuable kind is obtained from the so-called Pitch Lake.

The term *land* or *overflow* pitch is applied to the deposits of asphaltum found outside the lake. These deposits form extensive beds of variable thickness, and are covered with from a few to several feet of earth; they are considered by some authorities to be formed from pitch which has overflowed from the lake; by others to be of entirely different origin. The name *cheese pitch* is given to such portions of the land pitch as more nearly resemble that obtained from the lake.

The term *iron pitch* is used to designate large and isolated masses of extremely hard asphaltum found both within and without the borders of the lake. It is supposed to have been formed by the action of heat caused by forest fires, which, sweeping over the softer pitch, removed its more volatile constituents.

The name *épurée* is given to asphaltum refined on the island of Trinidad. The process is conducted in a very crude manner, in large, open, cast-iron sugar boilers.

The characteristics of crude Trinidad asphaltum, both *lake* and *land,* are as follows: It is composed of bitumen mixed with fine sand, clay, and vegetable matter. Its specific gravity varies according to the impurities present, but is usually about 1.28. Its color, when freshly excavated, is a brown, which changes to black on exposure to the atmosphere. When freshly broken, it emits the usual bituminous odor. It is porous, containing gas cavities, and in consistency resembles cheese. If left long enough in the sun, the surface will soften and melt, and will finally flow into a more or less compact mass.

Refined Trinidad Asphaltum. The crude asphaltum is refined or purified by melting it in iron kettles or stills by the application of indirect heat.

The operation of refining proceeds as follows: During the heating, the water and lighter oils are evaporated; the asphaltum is liquefied; the vegetable matter rises to the surface, and is skimmed off; the earthy and siliceous matters settle to the bottom; and the liquid asphaltum is drawn off into old cement or flour barrels.

When the asphaltum is refined without agitation, the residue remaining in the still forms a considerable percentage of the crude material, frequently amounting to 12 per cent; and it was at one time considered that the greater the amount of this residue the better the

quality of the refined asphaltum. Since agitation has been adopted, however; the greater part of the earthy and siliceous matters is retained in suspension; and it has come to be considered just as desirable for a part of the surface mixture as the sand which is subsequently added. The refined asphaltum, if for local use, is generally converted into cement in the same still in which it was refined.

The average composition of both the land and lake varieties is shown by the following analyses:

Average Composition of Trinidad Asphaltum

Constituents	Lake		Land
	Hard	*Soft*	
	Per Cent	Per Cent	Per Cent
Water	27.85	34.10	26.62
Inorganic matter	26.38	25.05	27.57
Organic non-bituminous matter	7.63	6.35	8.05
Bitumen	38.14	34.50	37.76
	100.00	100.00	100.00
When the analyses are calculated to a basis of dry substances, the composition is: Inorganic matter	36.56	38.00	37.74
Organic matter not bitumen	10.57	9.64	10.68
Bitumen	52.87	52.36	51.58
	100.00	100.00	100.00
The substances volatilized in 10 hours at 400° F	3.66	12.24	0.86 to 1.37
The substances soften at	190° F.	170° F.	200° to 250° F.
" " flow at	200° F.	185° F.	210° to 328° F.

The characteristics of refined Trinidad asphaltum are as follows: The color is black, with a homogeneous appearance. At a temperature of about 70° F., it is very brittle, and breaks with a conchoidal fracture. It burns with a yellowish-white flame, and in burning emits an empyreumatic odor, and possesses little cementitious quality. To give it the required plasticity and tenacity, it is mixed while liquid with from 16 to 21 pounds of residuum oil to 100 pounds of asphaltum.

The product resulting from the combination is called *asphalt paving-cement.* Its consistency should be such that, at a temperature of from 70° to 80° F., it can be easily indented with the fingers, and on slight warming be drawn out in strings or threads.

Artificial Asphalt Pavements. The pavements made from Trinidad, Bermudez, California, and similar asphaltums, are composed of mechanical mixtures of asphaltic cement, sand, and stone-dust.

The sand should be equal in quality to that used for hydraulic cement mortar; it must be entirely free from clay, loam, and vegetable

impurities; its grains should be angular and range from coarse to fine.

The stone-dust is used to aid in filling the voids in the sand and thus reduce the amount of cement. The amount used varies with the coarseness of the sand and the quality of the cement, and ranges from 5 to 15 per cent. (The voids in sand vary from .3 to .5 per cent.)

As to the quality of the stone-dust, that from any durable stone is equally suitable. Limestone-dust was originally used, and has never been entirely discarded.

The paving composition is prepared by heating the mixed sand and stone-dust and the asphalt cement separately to a temperature of about 300° F. The heated ingredients are measured into a pug-mill and thoroughly incorporated. When this is accomplished, the mixture is ready for use. It is hauled to the street and spread with iron rakes to such depth as will give the required thickness when compacted (the finished thickness varies between 1½ and 2½ inches). The reduction of thickness by compression is generally about 40 per cent.

The mixture is sometimes laid in two layers. The first is called the **binder** or **cushion-coat**; it contains from 2 to 5 per cent more cement than the surface-coat; its thickness is usually ½ inch. The object of the binder course is to unite the surface mixture with the foundation, which it does through the larger percentage of cement that it contains, which, if put in the surface mixture, would render it too soft.

The paving composition is compressed by means of rollers and tamping irons, the latter being heated in a fire contained in an iron basket mounted on wheels. These irons are used for tamping such portions as are inaccessible to the roller—namely, gutters, around manhole heads, etc.

Two rollers are sometimes employed; one, weighing 5 to 6 tons and of narrow tread, is used to give the first compression; and the other, weighing about 10 tons and of broad tread, is used for finishing. The amount of rolling varies; the average is about 1 hour per 1,000 square yards of surface. After the primary compression, natural hydraulic or any impalpable mineral matter is sprinkled over the surface, to prevent the adhesion of the material to the roller and to give the surface a more pleasing appearance. When the asphalt is laid up to the curb, the surface of the portion forming the gutter is painted with a coat of hot cement.

Although asphaltum is a bad conductor of heat, and the cement

retains its plasticity for several hours, occasions may and do arise through which the composition before it is spread has cooled; its condition when this happens is analogous to hydraulic cement which has taken a "set," and the same rules which apply to hydraulic cement in this condition should be respected in regard to asphaltic cement.

The proportions of the ingredients in the paving mixture are not constant, but vary with the climate of the place where the pavement is to be used, the character of the sand, and the amount and character of the traffic that will use the pavement. The range in the proportion is as follows:

Formula for Asphaltic Paving Mixture

Asphalt cement	12 to 15 per cent.
Sand	70 to 83 " "
Stone-dust	5 to 15 " "

A cubic yard of the prepared material weighs about 4,500 pounds, and will lay the following amount of wearing-surface:

2½ inches thick	12 square yards.
2 " "	18 " "
1½ " "	27 " "

One ton of refined asphaltum makes about 2,300 pounds of asphalt cement, equal to about 3.4 cubic yards of surface material.

Foundation. A solid, unyielding foundation is indispensable with all asphaltic pavements, because asphalt of itself has no power of offering resistance to the action of traffic, consequently it is nearly always placed upon a bed of hydraulic cement concrete. The concrete must be thoroughly set and its surface dry before the asphalt is laid upon it; if not, the water will be sucked up and converted into steam, with the result that coherence of the asphaltic mixture is prevented, and, although its surface may be smooth, the mass is really honeycombed, so that as soon as the pavement is subjected to the action of traffic, the voids or fissures formed by the steam appear on the surface, and the whole pavement is quickly broken up.

Advantages of Asphalt Pavement. These may be summed up as follows:

(1) Ease of traction.
(2) It is comparatively noiseless under traffic.
(3) It is impervious.
(4) It is easily cleansed.
(5) It produces neither mud nor dust.
(6) It is pleasing to the eye.

(7) It suits all classes of traffic.

(8) There is neither vibration nor concussion in traveling over it.

(9) It is expeditiously laid, thereby causing little inconvenience to traffic.

(10) Openings to gain access to underground pipes are easily made.

(11) It is durable.

(12) It is easily repaired.

Defects of Asphalt Pavement. These are as follows:

(1) It is slippery under certain conditions of the atmosphere. The American asphalts are much less so than the European, on account of their granular texture derived from the sand. The difference is very noticeable; the European are as smooth as glass, while the American resemble fine sandpaper.

(2) It will not stand constant moisture, and will disintegrate if excessively sprinkled.

(3) Under extreme heat it is liable to become so soft that it will roll or creep under traffic and present a wavy surface; and under extreme cold there is danger that the surface will crack and become friable.

(4) It is not adapted to grades steeper than 2½ per cent, although it is in use on grades up to 7.30 per cent.

(5) Repairs must be quickly made, for the material has little coherence, and if, from irregular settlement of foundation or local violence, a break occurs, the passing wheels rapidly shear off the sides of the hole, and it soon assumes formidable dimensions.

The strewing of sand upon asphalt renders it less slippery; but in addition to the interference of the traffic while this is being done, there are further objections—namely, the possible injury by the sand cutting into the asphalt, the expense of labor and materials, and the mud formed, which has afterwards to be removed.

Although pure asphaltum is absolutely impervious and insoluble in either fresh or salt water, yet asphalt pavements in the continued presence of water are quickly disintegrated. Ordinary rain or daily sprinkling does not injure them when they are allowed to become perfectly dry again. The damage is most apparent in gutters and adjacent to overflowing drinking fountains. This defect has long been recognized; and various measures have been taken to overcome it, or

at least to reduce it to a minimum. In some cities, ordinances have been passed, seeking to regulate the sprinkling of the streets; and in many places the gutters are laid with stone or vitrified brick (see Figs.

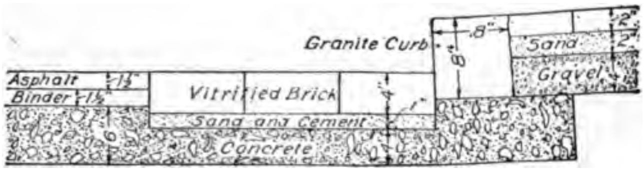

Fig. 64.

64 and 65), while in others the asphalt is laid to the curb, a space of 12 to 15 inches along the curb being covered with a thin coating of asphalt cement.

Asphalt laid adjoining center-bearing street-car rails is quickly broken down and destroyed. This defect is not peculiar to asphalt. All other materials when placed in similar positions are quickly worn. Granite blocks laid along such tracks have been cut into at a rate of more than half an inch a year. The frequent entering and turning off of vehicles from car tracks is one of the severest tests that can be

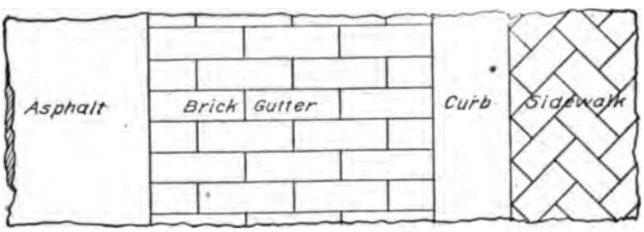

Fig. 65.

applied to any paving material; moreover, the gauge of trucks and vehicles is frequently greater than that of the rails, so one wheel runs on the rail and the other outside. The number of wheels thus traveling in one line must quickly wear a rut in any material adjoining the center-bearing rail.

To obviate the destruction of asphalt in such situations, it is usual to lay a strip of granite block or brick paving along the rail. This pavement should be of sufficient width to support the wheels of the widest gauge using the street.

The burning of leaves or making of fires on asphalt pavements should not be permitted, as it injures the asphalt, and the paving companies cannot be compelled to repair the damaged places without compensation.

Asphalt Blocks. Asphalt paving blocks are formed from a mixture of asphaltic cement and crushed stone in the proportion of 8 to 12 per cent of cement to 88 and 92 per cent of stone. The materials are heated to a temperature of about 300° F., and mixed while hot in a suitable vessel. When the mixing is complete, the material is placed in moulds and subjected to heavy pressure, after which the blocks are cooled suddenly by plunging into cold water.

The usual dimensions of the blocks are 4 inches wide, 3 inches deep, and 12 inches long.

Foundation. The blocks are usually laid upon a concrete foundation with a cushion-coat of sand about ½ inch thick. They are laid with their length at right angles to the axis of the street, and the longitudinal joints should be broken by a lap of at least 4 inches. The blocks are then either rammed with hand rammers or rolled with a light steam roller, the surface being covered with clean, fine sand; no joint filling is used, as, under the action of the sun and traffic, the blocks soon become cemented.

The advantages claimed for a pavement of asphalt blocks over a continuous sheet of asphalt are: (1) That they can be made at a factory located near the materials, whence they can be transported to the place where they are to be used and can be laid by ordinary paviors, whereas sheet pavements require special machinery and skilled labor; (2) that they are less slippery, owing to the joints and the rougher surface due to the use of crushed stone.

Asphalt Macadam—Bituminous Macadam. Recently it has been proposed to use asphalt as a binding material for broken stone. There are two patented processes—the Whinery and the Warren—which differ slightly in details.

The advantages claimed for these methods are: (1) The first coat will be materially less; (2) it will offer a better foothold for horses; (3) it will be at least as durable as the ordinary sheet asphalt; (4) it will not shift under traffic and roll into waves; (5) it will not crack; (6) it

can be repaired more cheaply and with less skilled labor than can the ordinary sheet asphalt.

Tools Employed in Construction of Asphalt Pavements. The

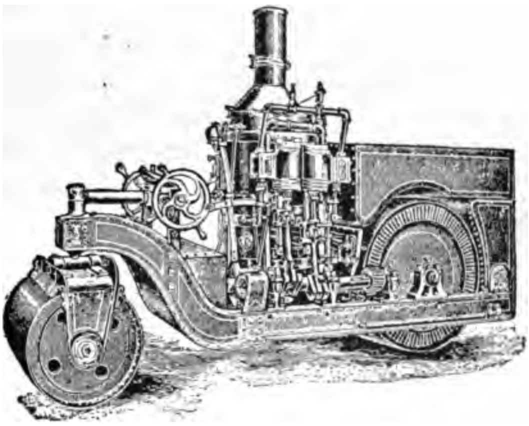

Fig. 66. Steam Roller.

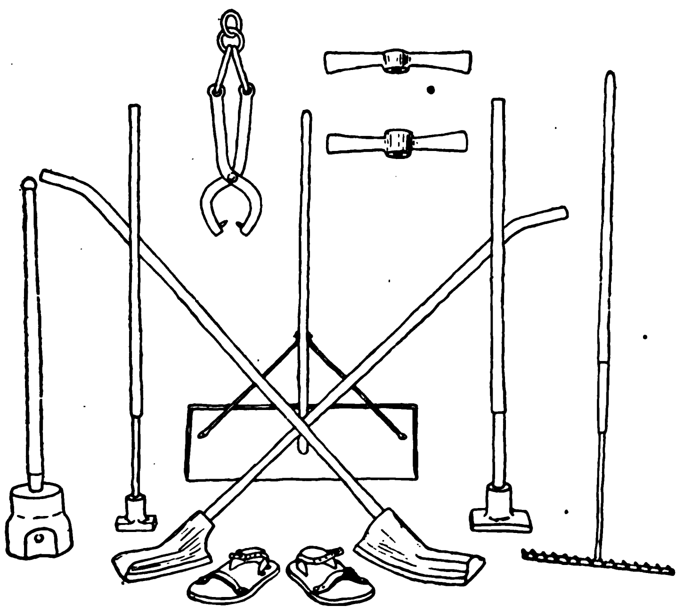

Fig. 67. Asphalt Tools.

tools used in laying sheet asphalt pavements comprise iron rakes; hand rammers; smoothing irons (Fig. 67); pouring pots (Fig. 69);

hand rollers, either with or without a fire-pot (Fig. 68); and steam rollers, with or without provision for heating the front roll (Fig. 66). These rollers are different in construction, appearance, and weight

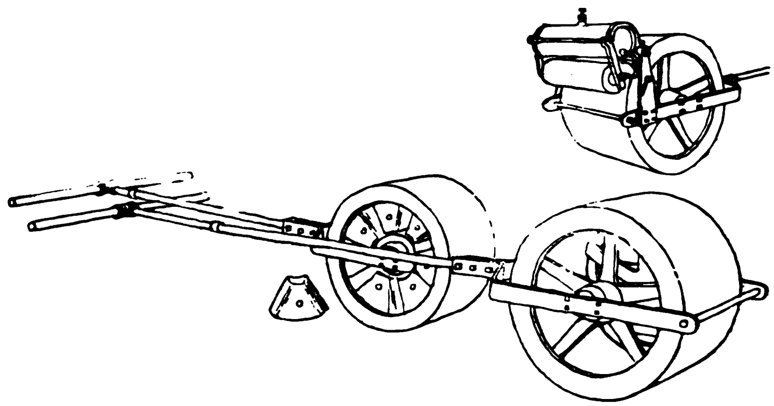

Fig. 68. Hand Rollers.

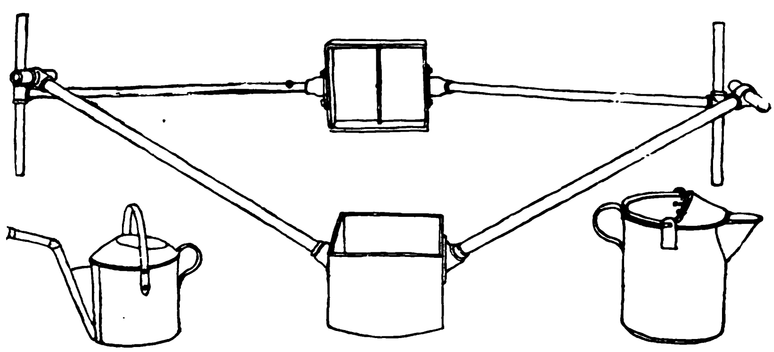

Fig. 69. Pouring Pots.

from those employed for compacting broken stone. The difference is due to the different character of the work required.

The principal dimensions of a five-ton roller are as follows:

Front roll or steering-wheel	30 to 32 inches diameter.
Rear roll or driving-wheel	48 " "
Width of front roll	40 " "
" " rear "	40 " "
Extreme length	14 feet.
" height	7 to 8 feet.
Water capacity	80 to 100 gallons.
Coal "	200 pounds.

FOOTPATHS—CURBS—GUTTERS.

A footpath or walk is simply a road under another name—a road for pedestrians instead of one for horses and vehicles. The only difference that exists is in the degree of service required; but the conditions of consruction that render a road well adapted to its object are very much the same as those required for a walk.

The effects of heavy loads such as use carriageways are not felt upon footpaths; but the destructive action of water and frost is the same in either case, and the treatment to counteract or resist these elements as far as practicable, and to produce permanency, must be the controlling idea in each case, and should be carried out upon a common principle. It is not less essential that a walk should be well adapted to its object than that a road should be; and it is annoying to find it impassable or insecure and in want of repair when it is needed for convenience or pleasure. In point of economy, there is the same advantage in constructing a footway skilfully and durably as there is in the case of a road.

Width. The width of footwalks (exclusive of the space occupied by projections and shade trees) should be ample to accomodate comfortably the number of people using them. In streets devoted entirely to commercial purposes, the clear width should be at least one-third the width of the carriageway; in residential and suburban streets, a very pleasing result can be obtained by making the walk one-half the width of the roadway, and devoting the greater part to grass and shade trees.

Cross Slope. The surface of footpaths must be sloped so that the surface water will readily flow to the gutters. This slope need not be very great; $\frac{1}{8}$ inch per foot will be sufficient. A greater slope with a thin coating of ice upon it, becomes dangerous to pedestrians.

Foundation. As in the case of roadways, so with footpaths, the foundation is of primary importance. Whatever material may be used for the surface, if the foundation is weak and yielding, the surface will settle irregularly and become extrémely objectionable, if not dangerous, to pedestrians.

Surface. The requirements of a good covering for sidewalks are:

(1) It must be smooth but not slippery.

(2) It must absorb the minimum amount of water, so that it may dry rapidly after rain.

(3) It must not be easily abraded.

(4) It must be of uniform quality throughout, so that it may wear evenly.

(5) It must neither scale nor flake.

(6) Its texture must be such that dust will not adhere to it.

(7) It must be durable.

Materials. The materials used for footpaths are as follows: Stone, natural and artificial; wood; asphalt; brick; tar concrete; and gravel.

Of the natural stones, sandstone (bluestone) and granite are extensively employed.

The bluestone, when well laid, forms an excellent paving material. It is of compact texture, absorbs water to a very limited extent, and hence soon dries after rain; it has sufficient hardness to resist abrasion, and wears well without becoming excessively slippery.

Granite, although exceedingly durable, wears very slippery, and its surface has to be frequently roughened.

Slabs, of whatever stone, must be of equal thickness throughout their entire area; the edges must be dressed true to the square for the whole thickness (edges must not be left feathered as shown in Fig. 70); and the slabs must be solidly bedded on the foundation and the joints filled with cement-mortar.

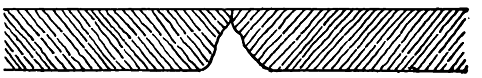

Fig. 70.

Badly set or faultily dressed flagstones are very unpleasant to walk over, especially in rainy weather; the unevenness causes pedestrians to stumble, and rocking stones squirt dirty water over their clothes.

Wood has been largely used in the form of planks; it is cheap in first cost, but proves very expensive from the fact that it lasts but a comparatively short time and requires constant repair to keep it from becoming dangerous.

Asphalt forms an excellent footway pavement; it is durable and does not wear slippery.

Brick. Brick of suitable quality, well and carefully laid on a concrete foundation, makes an excellent footway pavement for resi-

dential and suburban streets of large cities, and also for the main streets of smaller towns. The bricks should be a good quality of paving brick (ordinary building brick are unsuitable, as they soon wear out and are easily broken). The bricks should be laid in parallel rows on their edges, with their length at right angles to the axis of the path.

Curbstones. Curbstones are employed for the outer side of footways, to sustain the coverings and form the gutter. Their upper edges are set flush with the footwalk pavement, so that the water can flow over them into the gutters.

The disturbing forces which the curb has to resist, are: (1) The pressure of the earth behind it, which is frequently augmented by piles of merchandise, building materials, etc. This pressure tends to overturn it, break it transversely, or move it bodily on its base. (2) The pressure due to the expansion of freezing earth behind and beneath it. This force is most frequent where the sidewalk is partly sodded and the ground is accordingly moist. Successive freezing and thawing of the earth behind the curb will occasion a succession of thrusts forward, which, if the curb be of faulty design, will cause it to incline several degrees from the vertical. (3) The concussions and abrasions caused by traffic. To withstand the destructive effect of wheels, curbs are faced with iron; and a concrete curb with a rounded edge of steel has been patented and used to some extent. Fires built in the gutters deface and seriously injure the curb. Posts and trees set too near the curb, tend to break, displace, and destroy it.

The use of drain tiles under the curb is a subject of much difference of opinion among engineers. Where the subsoil contains water naturally, or is likely to receive it from outside the curb-lines, the use of drains is of decided benefit; but great care must be exercised in jointing the drain-tiles, lest the soil shall be loosened and removed, causing the curb to drop out of alignment.

The materials employed for curbing are the natural stones, as granite, sandstone (bluestone), etc., artificial stone, fire-clay, and cast iron.

The dimensions of curbstones vary considerably in different localities and according to the width of the footpaths; the wider the path, the wider should be the curb. It should, however, never be less than 8 inches deep, nor narrower than 4 inches. Depth is necessary

to prevent the curb turning over toward the gutter. It should never be in smaller lengths than 3 feet. The top surface should be beveled off to conform to the slope of the footpath. The front face should be hammer-dressed for a depth of about 6 inches, in order that there may be a smooth surface visible against the gutter. The back for 3 inches

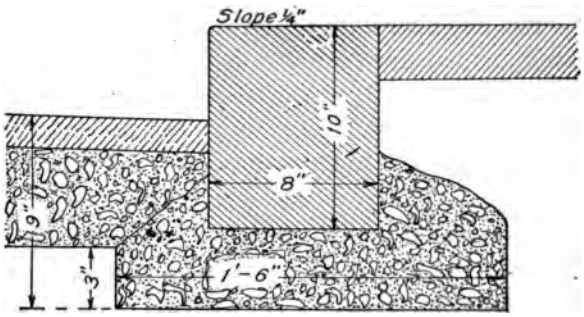

Fig. 71.

from the top should also be dressed, so that the flagging or other paving may butt fair against it. The end joints should be cut truly square, the full thickness of the stone at the top, and so much below the top as will be exposed, the remaining portion of the depth and bottom should be roughly squared, and the bottom should be fairly parallel to the top. (See Figs. 71 and 72).

Artificial Stone. Artificial stone is being extensively used as a

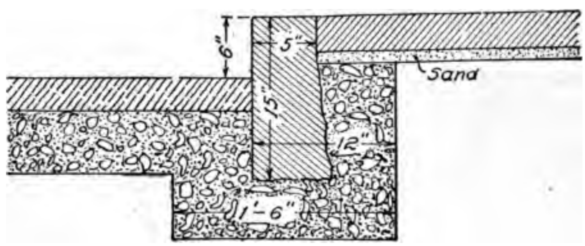

Fig. 72.

footway paving material. Its manufacture is the subject of several patents, and numerous kinds are to be had in the market. When manufactured of first-class materials and laid in a substantial manner, with proper provision against the action of frost, artificial stone forms a durable, agreeable, and inexpensive pavement.

The varieties most extensively used in the United States are known by the names of *granolithic, monolithic, ferrolithic, kosmocrete, metalithic,* etc.

The process of manufacture is practically the same for all kinds, the difference being in the materials employed. The usual ingredients are Portland cement, sand, gravel, and crushed stone.

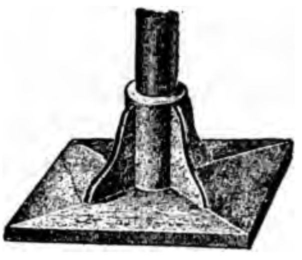

Fig. 73. Tamper.

Artificial stone for footway pavements is formed in two ways—namely, in blocks manufactured at a factory, brought on the ground, and laid in the same manner as natural stone; or the raw materials are brought upon the work, prepared, and laid in place, blocks being formed by the use of board moulds.

The manner of laying is practically the same for all kinds. The area to be paved is excavated to a minimum depth of 8 inches, and to such greater depths as the nature of the ground may require to secure a solid foundation. The surface of the ground so exposed is well compacted by ramming; and a layer of gravel, ashes, clinker, or other suitable material is spread and consolidated; on this is placed the concrete wearing surface, usually 4 inches thick. As a protection against the lifting effects of frost, the concrete is laid in squares, rectangles, or other forms having areas ranging from 6 to 30 square feet, strips of wood being employed to form moulds in which the concrete is placed. After the concrete is set, these strips are removed, leaving joints about half an inch wide between the blocks. Under some patents these joints are filled with cement; under others, with tarred paper; and in some cases they are left open.

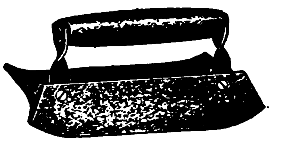

Fig. 74. Quarter-Round.

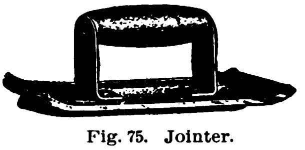

Fig. 75. Jointer.

Tools Employed in Construction of Artificial Stone Pavements. Tampers (Fig. 73). Cast iron, with hickory handle; range from 6 by 8 inches to 8 by 10 inches.

Quarter-Round, (Fig. 74). Made of any desired radius. Used for forming corners and edges.

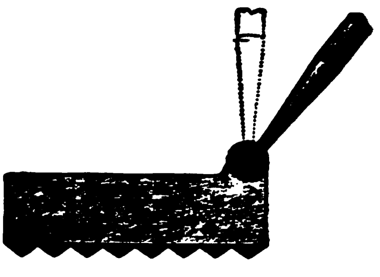

Fig. 76. Cutter.

Jointer (Fig. 75). Used for trimming and finishing the joints.

Cutter (Fig. 76). Used for cutting the concrete into blocks.

Gutter Tool (Fig. 77). Used for forming and finishing gutters.

Imprint Rollers (Figs. 78 and 79). Here are shown two designs of rollers for imprinting the surface of artificial stone pavements with grooves, etc.

SELECTING THE PAVEMENT

The problem of selecting the best pavement for any particular case is a local one, not only for each city, but also for each of the various parts into which the city is imperceptibly divided; and it involves so many elements that the nicest balancing of the relative values for each kind of pavement is required, to arrive at a correct conclusion.

In some localities, the proximity of one or more paving materials determines the character of the pavement; while in other cases a careful investigation may be required in order to select the most suitable material. Local conditions should always be considered; hence it is not possible to lay down any fixed rule as to what material makes the best pavement.

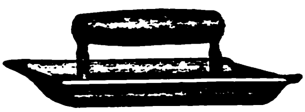

Fig. 77. Gutter Tool.

The qualities essential to a good pavement may be stated as follows:

(1) It should be impervious.

(2) It should afford good foothold for horses.

(3) It should be hard and durable, so as to resist wear and disintegration.

(4) It should be adapted to every grade.

(5) It should suit every class of traffic.

(6) It should offer the minimum resistance to traction.

(7) It should be noiseless.

(8) It should yield neither dust nor mud.

(9) It should be easily cleaned.

(10) It should be cheap.

Interests Affected in Selection. Of the above requirements, numbers 2, 4, 5, and 6 affect the traffic and determine the cost of haulage by the limitations of loads, speed, and wear and tear of horses and vehicles. If the surface is rough or the foothold bad, the weight of the load a horse can draw is decreased, thus necessitating the making of more trips or the employment of more horses and vehicles to move a given weight. A defective surface necessitates a reduction in the speed of movement and consequent loss of time; it increases the wear of horses, thus decreasing their life service and lessening the value of their current services; it also increases the cost of maintaining vehicles and harness.

Fig. 78. Imprint Roller.

Numbers 7, 8, and 9 affect the occupiers of adjacent premises, who suffer from the effect of dust and noise; they also affect the owners of said premises, whose income from rents is diminished where these disadvantages exist. Numbers 3 and 10 affect the taxpayers alone—first, as to the length of time during which the covering remains serviceable; and second, as to the amount of the annual repairs. Number 1 affects the adjacent occupiers principally on hygienic grounds. Numbers 7 and 8 affect both traffic and occupiers.

Fig. 79. Imprint Roller.

Problem Involved in Selection. The problem involved in the selection of the most suitable pavement consists of the following factors: (1) adaptability; (2) desirability; (3) serviceability; (4) durability; (5) cost.

Adaptability. The best pavement for any given roadway will

depend altogether on local circumstances. Pavements must be adapted to the class of traffic that will use them. The pavement suitable for a road through an agricultural district will not be suitable for the streets of a manufacturing center; nor will the covering suitable for heavy traffic be suitable for a pleasure drive or for a residential district.

General experience indicates the relative fitness of the several materials as follows:

For country roads, suburban streets, and pleasure drives—broken stone. For streets having heavy and constant traffic—rectangular blocks of stone, laid on a concrete foundation, with the joints filled with bituminous or Portland cement grout. For streets devoted to retail trade, and where comparative noiselessness is essential—asphalt, wood, or brick.

Desirability. The desirability of a pavement is its possession of qualities which make it satisfactory to the people using and seeing it. Between two pavements alike in cost and durability, people will have preferences arising from the condition of their health, presonal prejudices, and various other intangible influences, causing them to select one rather than the other in their respective streets. Such selections are often made against the demonstrated economies of the case, and usually in ignorance of them. Whenever one kind of pavement is more economical and satisfactory to use than is any other, there should not be any difference of opinion about securing it, either as a new pavement or in the replacement of an old one.

The economic desirability of pavements is governed by the ease of movement over them, and is measured by the number of horses or pounds of tractive force required to move a given weight—usually one ton—over them. The resistance offered to traction by different pavements is shown in the following table:

Resistance to Traction on Different Pavements

Kind of Pavement	Tractive Resistance	
	Pounds per ton	*In terms of the load*
Asphalt (sheet)	30 to 70	$\frac{1}{67}$ to $\frac{1}{30}$
Brick	15 " 40	$\frac{1}{133}$ " $\frac{1}{50}$
Cobblestones	50 " 100	$\frac{1}{40}$ " $\frac{1}{20}$
Stone-block	30 " 80	$\frac{1}{67}$ " $\frac{1}{25}$
Wood-block rectangular	30 " 50	$\frac{1}{67}$ " $\frac{1}{40}$
Wood-block round	40 " 80	$\frac{1}{50}$ " $\frac{1}{25}$

Serviceability. The serviceability of a pavement is its quality of fitness for use. This quality is measured by the expense caused to the traffic using it—namely, the wear and tear of horses and vehicles, loss of time, etc. No statistics are available from which to deduce the actual cost of wear and tear.

The serviceability of any pavement depends in great measure upon the amount of foothold afforded by it to the horses—provided, however, that its surface be not so rough as to absorb too large a percentage of the tractive energy required to move a given load over it. Cobblestones afford excellent foothold, and for this reason are largely employed by horse-car companies for paving between the rails; but the resistance of their surface to motion requires the expenditure ot about 40 pounds of tractive energy to move a load of 1 ton. Asphalt affords the least foothold; but the tractive force required to overcome the resistance it offers to motion is only about 30 pounds per ton.

Comparative Safety. The comparison of pavements in respect of safety, is the average distance traveled before a horse falls. The materials affording the best foothold for horses are as follows, stated in the order of their merit:

(1) Earth, dry and compact.
(2) Gravel.
(3) Broken stone (macadam).
(4) Wood.
(5) Sandstone and brick.
(6) Asphalt.
(7) Granite blocks.

Durability. The durability of pavement is that quality which determines the length of time during which it is serviceable, and does not relate to the length of time it has been down. The only measure of durability of a pavement *is the amount of traffic tonnage it will bear before it becomes so worn that the cost of replacing it is less than the expense incurred by its use.*

As a pavement is a construction, it necessarily follows that there is a vast difference between the durability of the pavement and the durability of the materials of which it is made. Iron is eminently durable; but, as a paving material, it is a failure.

Durability and Dirt. The durability of a paving material will vary considerably with the condition of cleanliness observed. One

inch of overlying dirt will most effectually protect the pavement from abrasion, and indefinitely prolong its life. But the dirt is expensive, it injures apparel and merchandise, and is the cause of sickness and discomfort. In the comparison of different pavements, no traffic should be credited to the dirty one.

Life of Pavements. The life or durability of different pavements under like conditions of traffic and maintenance, may be taken as follows:

Life Terms of Various Pavements

MATERIAL	LIFE TERM
Granite block	12 to 30 years
Sandstone	6 " 12 "
Asphalt	10 " 14 "
Wood	3 " 7 "
Limestone	1 " 3 "
Brick	5 " ? "
Macadam	5 " ? "

Cost. The question of cost is the one which usually interests taxpayers, and is probably the greatest stumbling-block in the attainment of good roadways. The first cost is usually charged against the property abutting on the highway to be improved. The result is that the average property owner is always anxious for a pavement that costs little, because he must pay for it, not caring for the fact that cheap pavements soon wear out and become a source of endless annoyance and expense. Thus false ideas of economy always have stood, and undoubtedly to some extent always will stand, in the way of realizing that the best is the cheapest.

The pavement which has cost the most is not always the best; nor is that which cost the least the cheapest; *the one which is truly the cheapest is the one which makes the most profitable returns in proportion to the amount expended upon it.* No doubt there is a limit of cost to go beyond which would produce no practical benefit; but it will always be found more economical to spend enough to secure the best results, and this will always cost less in the long run. One dollar well spent is many times more effective than one-half the amount injudiciously expended in the hopeless effort to reach sufficiently good results. The cheaper work may look as well as the more expensive for the time, but may very soon have to be done over again.

Economical Benefit. The economic benefit of a good roadway is

comprised in its cheaper maintenance; the greater facility it offers for traveling, thus reducing the cost of transportation; the lower cost of repairs to vehicles, and less wear of horses, thus increasing their term of serviceability and enhancing the value of their present service; the saving of time; and the ease and comfort afforded to those using the roadway.

First Cost. The cost of construction is largely controlled by the locality of the place, its proximity to the particular material used, and the character of the foundation.

The Relative Economies of Pavements—whether of the same kind in different condition, or of different kinds in like good condition —are sufficiently determined by summing their cost under the following headings of account:

(1) Annual interest upon first cost.
(2) Annual expense for maintenance.
(3) Annual cost for cleaning and sprinkling.
(4) Annual cost for service and use.
(5) Annual cost for consequential damages.

Interest on First Cost. The first cost of a pavement, like any other permanent investment, is measurable for purposes of comparison by the amount of annual interest on the sum expended. Thus, assuming the worth of money to be 4%, a pavement costing $4 per square yard entails an annual interest loss or tax of $0.16 per square yard.

Cost of Maintenance. Under this head must be included all outlays for repairs and renewals which are made from the time when the pavement is new and at its best to a time subsequent, when, by any treatment, it is again put in equally good condition. The gross sum so derived, divided by the number of years which elapse between the two dates, gives an average annual cost for maintenance.

Maintenance means the keeping of the pavement in a condition practically as good as when first laid. The cost will vary considerably depending not only upon the material and the manner in which it is constructed, but upon the condition of cleanliness observed, and the quantity and quality of the traffic using the pavement.

The prevailing opinion that no pavement is a good one unless, when once laid, it will take care of itself, is erroneous; *there is no such pavement.* All pavements are being constantly worn by traffic and by the action of the atmosphere; and if any defects which appear are

not quickly repaired, the pavements soon become unsatisfactory and are destroyed. To keep them in good repair, incessant attention is necessary, and is consistent with economy. Yet claims are made that particular pavements cost little or nothing for repairs, simply because repairs in these cases are not made, while any one can see the need of them.

Cost of Cleaning and Sprinkling. Any pavement, to be considered as properly cared for, must be kept dustless and clean. While circumstances legitimately determine in many cases that streets must be cleaned at daily, weekly, or semi-weekly intervals, the only admissible condition for the purpose of analysis of street expenses must be that of like requirements in both or all cases subjected to comparison.

The cleaning of pavements, as regards both efficiency and cost, depends (1) upon the character of the surface; (2) upon the nature of the materials of which the pavements are composed. Block pavements present the greatest difficulty; the joints can never be perfectly cleaned. The order of merit as regards facility of cleansing, is: (1) asphalt, (2) brick, (3) stone, (4) wood, (5) macadam.

Cost of Service and Use. The annual cost for service is made up by combining several items of cost incidental to the use of the pavement for traffic—for instance, the limitation of the speed of movement, as in cases where a bad pavement causes slow driving and consequent loss of time; or cases where the condition of a pavement limits the weight of the load which a horse can haul, and so compels the making of more trips or the employment of more horses and vehicles; or cases where conditions are such as to cause greater wear and tear of vehicles, of equipage, and of horses. If a vehicle is run 1,500 miles in a year, and its maintenance costs $30 a year, then the cost of its maintenance per mile traveled is two cents. If the value of a team's time is, say, $1 for the legitimate time taken in going one mile with a load, and in consequence of bad roads it takes double that time, then the cost to traffic from having to use that one mile of bad roadway is $1 for each load. The same reasoning applies to circumstances where the weight of the load has to be reduced so as to necessitate the making of more than one trip. Again, bad pavements lessen not only the life-service of horses, but also the value of their current service.

Cost for Consequential Damages. The determination of consequential damages arising from the use of defective or unsuitable pave-

ments, involves the consideration of a wide array of diverse circumstances. Rough-surfaced pavements, when in their best condition, afford a lodgment for organic matter composed largely of the urine and excrement of the animals employed upon the roadway. In warm and damp weather, these matters undergo putrefactive fermentation, and become the most efficient agency for generating and disseminating noxious vapors and disease germs, now recognized as the cause of a large part of the ills afflicting mankind. Pavements formed of porous materials are objectionable on the same, if not even stronger, grounds.

Pavements productive of dust and mud are objectionable, and especially so on streets devoted to retail trade. If this particular disadvantage be appraised at so small a sum per lineal foot of frontage as $1.50 per month, or six cents per day, it exceeds the cost of the best quality of pavement free from these disadvantages.

Rough-surfaced pavements are noisy under traffic and insufferable to nervous invalids, and much nervous sickness is attributable to them. To all persons interested in nervous invalids, this damage from noisy pavements is rated as being far greater than would be the cost of substituting the best quality of noiseless pavement; but there are, under many circumstances, specific financial losses, measurable in dollars and cents, dependent upon the use of rough, noisy pavements. They reduce the rental value of buildings and offices situated upon streets so paved—offices devoted to pursuits wherein exhausting brain work is required. In such locations, quietness is almost indispensable, and no question about the cost of a noiseless pavement weighs against its possession. When an investigator has done the best he can to determine such a summary of costs of a pavement, he may divide the amount of annual tonnage of the street traffic by the amount of annual costs, and know what number of tons of traffic are borne for each cent of the average annual cost, which is the crucial test for any comparison, as follows:

(1) Annual interest upon first cost........................$
(2) Average annual expense for maintenance and renewal...
(3) Annual cost for custody (sprinkling and cleaning)......
(4) Annual cost for service and use........................
(5) Annual cost for consequential damages..................
Amount of average annual cost..............................
Annual tonnage of traffic..................................
Tons of traffic for each cent of cost......................

Gross Cost of Pavements. Since the cost of a pavement depends

upon the material of which it is formed, the width of the roadway, the extent and nature of the traffic, and the condition of repair and cleanliness in which it is maintained, it follows that in no two streets is the endurance or the cost the same, and the difference between the highest and lowest periods of endurance and amount of cost is very considerable.

The comparative cost of the various street pavements, including interest on first cost, sinking fund, maintenance, and cleaning, when reduced to a uniform standard traffic of 100,000 tons per annum for each yard in width of the carriageway, is about as follows:

Comparative Cost of Various Pavements

MATERIAL	ANNUAL COST PER SQ. YD.
Granite blocks	$0.25
Asphalt street	0.40
Brick	0.35
Wood	0.50

23rd. Examination Paper.

23nd. Examination Paper.

EXAMINATION PAPER

"Excellent"

HIGHWAY CONSTRUCTION

PART II

Read Carefully: Place your name and full address at the head of the paper. Any cheap, light paper like the sample previously sent you may be used. Do not crowd your work, but arrange it neatly and legibly. *Do not copy the answers from the Instruction Paper; use your own words, so that we may be sure you understand the subject.*

1. How should the natural soil be prepared to receive a pavement?
2. In ramming blocks in the pavement, what point requires to be watched?
3. How is a sand cushion prepared for use?
4. What influences the durability of a granite?
5. How are rectangular stones laid on steep grades?
6. How is the surface and sub-surface drainage of streets provided for?
7. What are the principal objections to wood pavements?
8. What determines the best width for a street?
9. In filling the joints with gravel and bituminous cement, what should be the condition of the material?
10. What controls the maximum grade for a given street?
11. What varieties of wood give the most satisfactory results?
12. To what tests are stones intended for paving subjected?
13. Do cobblestones form a satisfactory pavement?
14. What properties should a stone possess to produce a satisfactory paving block?
15. How are expansion joints formed in a pavement?
16. What is the most suitable material for the foundation of a pavement?
17. Under what class of traffic may wood be used?
18. Upon what does the durability of a pavement depend?
19. What materials are employed for filling the joints between the paving blocks?

20. How should the grades be arranged at the intersection of streets on steep grades?

21. What are the defects of granite block paving laid on a sand foundation?

22. Under what class of traffic are bricks durable?

23. How should rectangular stones be laid in a pavement and why?

24. What is the object of a cushion coat and of what should it be formed?

25. What is the most essential condition of a rectangular paving stone?

26. What determines the dimensions of a rectangular paving stone?

27. For what properties are paving bricks tested and how?

28. What class of pavements are most objectionable?

29. How is bituminous limestone prepared for use?

30. How is the most economical pavement determined?

31. What is the effect of creosoting wood?

32. In the selection of a pavement for a given street, what conditions should be considered?

33. How is the expansion of wood blocks provided for?

34. What is the office of a curb?

35. What are the essential qualities of the ingredients composing an asphalt pavement?

36. How is the durability of a pavement determined?

37. What are the essential requirements for a satisfactory footpath?

38. Is an asphalt pavement suited to all grades?

39. Upon what does the serviceability of a pavement depend?

40. What is the difference between a roadway and a footpath?

41. How are pavements made from Trinidad and similar asphalts?

After completing the work, add and sign the following statement:

I hereby certify that the above work is entirely my own.

(Signed)